GEOLOGY OF OTAGO.

HUTTON & ULRICH.

MILFORD SOUND, LOOKING WEST

REPORT

ON THE

GEOLOGY & GOLD FIELDS

OF

OTAGO.

BY

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AND

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WITH APPENDICES

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PART I.

GEOLOGY OF OTAGO,

BY

F. W. HUTTON, F.G.S.

Otago Museum, Dunedin, 14th June, 1875.

Sir,—I have the honor to forward herewith my report on the Geology of Otago, with map and sections. I have to tender my thanks to W. M. Hodgkins, Esq., for the two spirited sketches of Milford Sound and Mount Aspiring; and also to J. M'Kerrow, Esq., for the valuable table of altitudes attached to the report.

I have the honor to be,

Your obedient servant,

F. W. HUTTON,

Provincial Geologist.

His Honor

J. Macandrew, Esq.,

Superintendent.

INTRODUCTION.

It is necessary that I should preface my report with a few remarks that will help the reader to judge how much reliance can be placed on the accuracy of the map accompanying it, and on the conclusions that I have arrived at.

In the months of January and February, 1872, I examined, under instructions from Dr. Hector, Director of the Geological Survey of New Zealand, the Southland district. In October, 1873, I was appointed Provincial Geologist in Otago, and during the ensuing summer, I rode over the north-western part of the Province, from the Waitaki to the Clutha, and in March, 1874, I visited the north part of Stewart Island and several of the sounds on the west coast in the Government steamer "Luna." In the summer of 1874-5 I examined, principally on horseback, the remaining part of the Province from the Clutha to the Waiau, thus completing my survey.

The map, on a scale of eight miles to an inch, provided me by the Provincial Survey Department, was well adapted for making a reconnaissance survey, as it was very accurate and on a sufficiently large scale for my purpose. But before any detailed geological survey can be made of the Province, it will be necessary to prepare a topographical map, on a scale of not less than one inch to a mile, showing all the physical features of the ground; for it is simply a waste of time and money attempting to put geological details on to a map that does not shew the true position and shape of every hill.

It cannot be supposed that in such a rapid survey as I have made of the Province, I could, single-handed, have filled in quite accurately all the boundaries of the different formations, but I feel tolerably confident in the general accuracy of the work, and hope that it will be found a safe foundation for future detailed surveys by the geological survey of New Zealand.

The map accompanying this report has been reduced to one-third of that furnished me by the survey office, as a larger one would be unnecessary and inconvenient for use when bound up with the report. I hold myself responsible for the whole of it except the valley of the Hollyford, and the northern boundary between the granite and the gneiss in the upper parts of Preservation and Chalky Inlets. These places I have not visited, but have filled in my map from the remarks on the rocks made by Dr. Hector in his report on his geological expedition to the west coast of Otago in 1863.

The sections are of course sketch sections, and only give roughly the relative altitude of the mountains. They are merely intended to be explanatory of the text, and make no pretence of having been drawn to scale.

In the arrangement of the report I have tried to bring out clearly the general geology of the Province, and in order to do this I have described the formations in stratigraphical order, and not by districts. This plan has the disadvantage of not enabling local geologists to find out the structure of their district so easily as if all that is known about it were brought together, but I hope that the copious index to localities will to some extent lessen this objection. On the other hand it has the advantage of obviating the necessity of constant repetitions, which are necessary when describing the same formation over again in each district.

In the section devoted to previous observers I have included all the various classifications that have been proposed for the rocks of New Zealand, for they have an intimate bearing on the geology of Otago, and a knowledge of them will give the reader a better idea of the differences of opinion that still have to be reconciled than he would have had if my remarks had been exclusively confined to this Province.

I have quoted rather largely from Dr. Hector's reports on the geology of the ManuherikiaPlains, and his narrative of geological exploration of the West Coast, for as they are printed only in the Provincial Government Gazette, they will not be accessible to most of my readers, while as he is the only other

geologist who has travelled over Otago, it is necessary that I should state his views as clearly as possible.

Many will no doubt think, if they do not say, that in the section on Physiography it would have been wiser for me to have kept back some of the ideas there put forth until I was in possession of many more facts to test them by, and I am quite willing to allow that it would have been so. But I have thought that the publication of these views, however crude they may be, would tend to stimulate enquiry throughout the Province, and would enable many observers, who have not the technical knowledge necessary to work out points in structural geology, to take part in the discussion of questions which are extremely interesting and important, and by no means easy of solution.

During the last eighteen months a considerable number of Otago fossils have been presented to the Museum, and among them are several undescribed species. I have, however, thought it better not to describe these species at present, for Dr. Hector has taken to England with him large collections of fossils from all parts of New Zealand, to be described there, and it is better for us to wait until this is done.

MT. ASPIRING, FROM THE MATUKITUKI

SECTION I.

PHYSICAL GEOGRAPHY.

The Province of Otago comprehends all that part of New Zealand south of the river Waitaki and a line from Lake Ohau through Mount Aspiring to Big Bay on the West Coast, and it contains, with Stewart Island, an area of about 20,876 square miles. It is essentially a mountainous country, the only very extensive flat land being the Southland plains, between the Hokanui and Moonlight ranges and the sea. Besides these, however, there are many smaller areas of flat or undulating country, and in the interior the Maniototo Plains, the Idaburn Valley, and Manuherika Plains are of considerable extent.

The highest land in the Province is situated in the north-west corner from Mt. Aspiring (9940ft), through Mt. Edward (8459ft), Mt. Tyndall (8116), Mt. Ansted (8157ft), Centaur Peak (8284ft), Cosmos Peak (8000ft), and Mt. Earnslaw (9165ft), to Mt. Christina (8475). Southward and eastward of this the mountains lower until they assume, towards the sea, with few exceptions, the form of rolling downs, averaging about 1500 feet above the sea level. Along the west coast, however, the mountains never lose their rugged character, and maintain an altitude in the highest peaks of between 4000 and 5000 feet as far as the south-west corner of the Province.

Sounds.

Along the western seaboard these mountains are penetrated by long winding sounds, or fiords, which are of great depth, but universally become shallower at their entrance into the sea. Not much is known yet as to the actual depth of these sounds, most of the soundings recorded giving no bottom at depths of from 150 to 900 feet. The deepest soundings on the chart are 1728 feet in Breaksea Sound off First Cove; 1500 feet in Thompson Sound, off Deas Cove; and 1284 feet in Milford Sound, off the Stirling waterfall. Bligh Sound seems to be the shallowest, the greatest depth being 468 feet, unless it be Preservation Inlet, where the greatest depth recorded is no bottom at 336 feet.

The entrances to most of the sounds vary in depth between 150 and 280 feet, the exceptions being Preservation Inlet with a depth of only 14 to 84 feet, Milford Sound with a depth of 360ft, Doubtful Sound with a depth of 372ft, and Thompson Sound with a depth of 456 ft. But of these, Doubtful Sound, although 372ft deep at the entrance, shallows to 150ft on either side of Banza

Island, so that, with the exception of Preservation, Thompson, and Milford, all the sounds have at their entrance an average depth of 215ft, with a limit of variation more or less of 65 feet.

The mountains that surround Preservation and Chalky Inlets are rounded in outline, and comparatively low, the sides being covered with bush down to the water's edge; but from Dusky northwards, high, almost perpendicular, cliffs are often seen, until in Milford Sound the land rises abruptly from the water in precipices 1500ft high (see frontispiece). These steep cliffs are, however, confined to the interior of the sounds, for the sea coast is nowhere high, but falls with a comparatively gentle slope nearly to the sea level. See fig. 21.

Lakes.

On the inland side of the west coast range the place of these sounds is taken by the arms of the Lakes Te Anau, Manipori, Monowai, and Howloko; and so far do these fresh water arms on the east and salt water sounds on the west penetrate into the heart of the mountains that in several places they approach to within nine or ten miles of each other.

To the north-east lies Lake Wakatipu, and further on in the same direction Lakes Wanaka and Hawea. These lakes present scenery unsurpassed probably in the world, for, unlike the Swiss lakes, they do not lie outside the principal mountain masses, but wind themselves close round their feet. Wanaka, which is perhaps the most beautiful lake in the world, and Wakatipu show glorious views of snowy mountains, to which Lucerne and Brienz cannot aspire. The great length of Te Anau in a straight line (38 miles) with the shoulders of the mountains, coming down one behind the other, gives a view totally unlike anything in Switzerland; while Manipori is dark and stern, but relieved by the green islands dotted over its surface.

Not much is yet known of the physical geography of these lakes, but what is known will be found in Mr. McKerrow's paper in the third volume of the 'Transactions of the New Zealand Institute.' Lake Wakatipu is the only one that has been sounded, and its greatest depth is said to be 1400ft, which is about 400ft below the level of the sea. This feature, however, is by no means peculiar to the lakes of Otago. All the large lakes of North America, except Lake Erie, and several of those in Italy, descend below the sea, while Loch Lomond, in Scotland, is 600ft deep, and only 20ft above the sea level.

The water in the southern half of Lake Wakatipu is as blue as the Rhone at Geneva, but near the head it turns a pale, milky colour, owing to the fine mud brought by the Dart and Rees from the glaciers of Mount Earnslaw and Cosmos Peak. In many places terraces fringe the lake, which prove that the water once

stood higher; but around the greater part these are absent. These terraces are generally found at the embouchures of the large streams, and owing to the steepness of the sides of the lake, no deposit is now forming at other places; so that these gravel beds are not continuous, and do not extend across the lake, although they are at the same level on both sides. Ultimately, however, as the lake fills up, they will be all connected.

The arms of Lake Te Anau and Manipori exactly resemble the sounds on the West Coast, and although the other lakes do not show the same abruptness of outline, still the valleys of the streams in the neighborhood have many analogies with the sounds. For instance, the Shotover River has no falls nor rapids in its course, but has cut a narrow gorge in the solid rock to a depth of about 200ft. (See fig. 16.) All the larger lateral streams have also cut down their channels to the same level, but some of the smaller ones enter the gorge by falls, just like Milford Sound. Again the gorges up the Routeburn are perpendicular and rough, exactly like those of the West Coast sounds in miniature. But away from the western mountains the scenery is quite different, and high, perpendicular precipices give way to gentler slopes and more rounded outlines.

Rivers.

All the rivers and nearly all the creeks in Otago are rapid streams, running over shingly or rocky beds. Like all mountain rivers they are liable to considerable fluctuation in level, a subject which in the case of the Taieri has been ably treated by Mr. J. T. Thomson, C.E.* and Mr. G. M. Barr, C.E.† Mr. Thomson also, in another paper,‡ has a very important discussion on the curves formed by the beds of the rivers Manuherikia, Waitaki, Shag, Taieri, Clutha, Cardrona, and Mataura, all of which he shows conform practically to the curve of the ellipse. This result is contrary to the general belief of geographers, who consider that the parabola is the curve which a river tends to assume from its source to its mouth. Mr. Thomson, however, considers that rivers tend to assume the curve of the ellipse only when they are hollowing out their beds, and that when they are raising them they tend to assume the curve of the parabola,§ but he offers no explanation of the cause of this difference. The Mataura is the only river in New Zealand with falls near its mouth.

Plains.

The Southland Plains have already been mentioned. They have a length of nearly forty miles with a breadth of about twenty-

*Appendix to the Votes and Proceedings of the Provincial Council of Otago, 1870.

†Trans. N.Z. Institute, v. p. 111.

‡Trans. N.Z. Institute, vi., p. 313.

§ l.c., p. 331.

six miles. A remarkable circumstance connected with these plains is that they are continued up the valleys of the Mataura, Oreti, and Jacob Rivers, and wrap completely round the hills that properly bound them inland, so that we might consider the Southland Plains as extending up to the Five River Plain, Long Ridge, and the Pyramid, out of which the Moonlight Range and Hokonui Hills stand like islands.

With the exception of the Waitaki plains and Inch Clutha, at the mouth of that river, all the other plains in Otago lie inland. The principal are the Maniototo plains, 28 miles long, and with an average breadth of about 10 miles; Idaburn Valley, with a length of 25 and a breadth of 4 miles; Manuherikia plains, with a length and breadth of about 35 and 4 miles respectively; and the Upper Clutha plains, with a length of 33 miles and an average breadth of about 5 or 6 miles. Plains of smaller extent are found in many other places, as at Strath Taieri, Lower Taieri, Tokomairiro, Tapanui, Moa Flat, &c. A considerable extent of land, some 70 miles in length by 20 in width, stretching from the Shag river between the Rock and Pillar and Silver Peak hills, through Waipori and Lawrence to the Clutha, may be considered as an elevated plain or plateau, some 1500 feet above the sea, and deeply cut through by the streams that cross it.

Mountains.

The distribution of the mountain ranges in the Province is very irregular and complicated; but to assist the memory of those who are not personally acquainted with the country, I may compare them roughly to the fingers of the right hand widely spread out, but with the first and second fingers approximated, and with the palm resting in the south-west part of the Province of Canterbury. In this case the thumb will represent the Hawkdun and Kakanui mountains, running north-west and south-east, which form the southern boundary of the valley of the Waitaki. The first finger will represent the Dunstan and Lammerlaw Ranges, running more or less north and south, which form the eastern watershed of the Clutha. The space between this finger and the thumb contains the large inland plains and the winding valley of the Taieri, and it is crossed in a south-west and north-east direction by four ranges, which lie at right angles to the general run of the mountains. These are Raggedy Range, Rough Ridge, Rock and Pillar Range, and the Silver Peak hills. The second or middle finger will represent all that rugged tract of country between Lakes Wanaka and Wakatipu, called the Harris and Richardson mountains, continued southwards in the Remarkables, Garvie mountains, Obelisk Range, and Umbrella mountains, and running through the Kaihiku mountains to the sea at Nugget Point. It is bounded by the Clutha on the east and the Mataura on the west. The third or ring finger will represent the

Humboldt mountains, the Thomson and Livingstone mountains, the Takitimus, and the Longwood range, having a general N.N.E. and S.S.W. direction, and lying between Lake Wakatipu and the Oreti river on the east, and the Hollyford river, Lake Te Anau, and the Waiau on the west. Between this finger and the middle finger lie the Southland plains, bounded on the north by the Hokanui and Moonlight ranges, which run in a north-west and south-east direction, or nearly at right angles to the general trend of the mountains And last, the little finger will represent the west coast range running in a north-east and south-west direction.

Coast Line.

The eastern sea board of the Province is formed generally by low hills and sandy beaches, interrupted by bold headlands where the harder rocks run out to sea. On the south, low cliffs run from the Nuggets to Preservation Inlet, except between the Mataura and Jacob rivers, where the Southland plains form the coast line. As might be expected the sea deepens more rapidly on the west coast than on the east, but contrary to expectation the south coast is shallower than either. The 100 fathom line keeps at an average distance of 25 miles from the east coast as far as the Nuggets, when it sweeps away south and includes Stewart Island and the Snares. Along the west coast little is known, but the depth seems variable. Foveaux Strait is nowhere more than 25 fathoms in depth, and an elevation of 130 feet would join Stewart Island on to the main land.

Comparison between the New Zealand and Swiss Alps.

No one, I think, who after visiting the Alps of Switzerland should explore the Alps of New Zealand, could fail to notice two remarkable points of difference between these mountain regions. The one is that mountains with sharp serrated summits, which are the exception in Switzerland, are the rule in New Zealand, and the other is that the numerous large waterfalls, which the traveller in Switzerland sees at almost every turn, are quite exceptional in New Zealand. A few waterfalls, but they are very few in comparison with Switzerland, are found in the deep fiords on the west coast, and a few smaller ones towards the heads of the valleys in the heart of the mountains, and these are nearly all. And yet the mountains in New Zealand are quite as rough and rugged as the Alps of Europe, and, indeed, the gorges are more numerous and deeper. There are also other minor points of difference. The passes in New Zealand are lower, and the mountains are in places much more covered with loose debris than any part of the Swiss Alps. But this last is a local peculiarity, and is not so noticeable in Otago as in Canterbury and Nelson.

Two theories may be put forward to explain these differences. One is that the New Zealand Alps are composed of rocks which

suffer from decay and degradation much more than the rocks that compose the Alps of Switzerland. The other is that the mountains of New Zealand are of far greater antiquity than the Swiss Alps, and have in consequence suffered a far greater amount of denudation. To any traveller in New Zealand who had limited his explorations to the Province of Otago, east of the great lakes, the first is the theory that would most naturally present itself to his mind, for all the mountains that he would have examined would have been composed of mica schist. But in the west of this Province the mountains are composed of hard gneiss, crossed by dykes of eruptive rocks; and further north, in the provinces of Canterbury, Nelson and Marlborough, the mountains are chiefly formed of sandstones and slates, as hard on the average as the rocks composing the Alps of Switzerland, and yet the phenomena that I have mentioned are quite as noticeable in those provinces as they are in Otago. On the other hand we have proofs in the geological structure of our mountains, as I shall presently show, that the New Zealand Alps have been constantly exposed to the action of rain and wind ever since the jurassic period, and that many of the larger valleys had been cut down nearly to their present depth in the eocene period, a time when the European Alps and the Himalayas were only just rising above the sea. Probably, therefore, the second theory is the more correct, but the first may reasonably be called in to explain local details.

Peculiarities in the Physical Geography of Otago.

Another remarkable fact in the sub-alpine part of Otago, or that portion which lies eastward of the great lakes, is that most of the larger rivers do not run in what we must consider as their natural channels, but constantly cross abruptly from one valley into another. For example, the Clutha, after arriving at Cromwell, ought to have continued straight on and joined the Frazer instead of cutting through the Dunstan Range. Lake Wakatipu should have emptied itself at Kingston into the Mataura, which, in its turn, instead of breaking through the gorge at Athol, should have continued by the Dome pass to the Five-river Plains, and there have joined the Oreti. The Upper Taieri and the Idaburn should have joined the Manuhirikia at Blackstone Hill. The Lower Taieri and the Tokomairiro should empty themselves into the Clutha near Kaitangata; while the Pomahaka should have joined the Mataura instead of the Clutha.

While also the larger rivers run almost always in narrow gorge-like valleys, many of the large valleys have but very insignificant streams flowing in them. Such, for example, are the Idaburn valley, the Manuherikia valley, the Tokomairiro plains, and the Waimea plains, which last are but a portion of the valley running from the Upper Oreti to Port Molyneux. The Taieri plains also

do not properly belong to that river at all, for they run up the valley of the Silverstream, while the Taieri breaks suddenly in upon them by a lateral gorge. These plains are really the valley of the Silverstream, which the Taieri has usurped.

It is these anomalies that physiography, or surface geology, undertakes to explain; and the explanation when obtained is not only curious and interesting, but it is highly important from a practical point of view; for it informs us of the successive oscillations in level that the land underwent while the surface features were being formed; and on these various oscillations of level the mode of deposition of the different river alluvia depends. But as some of these alluvia contain gold, it is evident that anything that throws light on their mode of deposition is of great importance to the alluvial gold miner.

Before, however, trying to explain the surface geology of the Province, it will be necessary to describe its geological structure, for unless this is first clearly understood, great and important errors are sure to get into our theories of the surface geology of the country.

SECTION II.

Previous Observers.

The first notice of the geology of any part of Otago was by the Hon. W. Mantell, who, in 1848, travelled from Kaiapoi, in Canterbury, to Dunedin, and the observations he then made were published in the Quarterly Journal of the Geological Society of London for 1850. The most important scientific result of this journey was the valuable collection of Moa bones made at Awamoa,* and from the swamp, at Waikouaiti, where Mr. Percy Earl had obtained his collection some three or four years previously. But many interesting notes on the geology will also be found in this paper. Mr. Mantell mentions the schists at Awamoko, which is the first record or this class of rocks in New Zealand, as also the limestones of the Kakanui river and Ototara, and the volcanic ash at Kakanui mouth. He also notices the blue clay of Moeraki, or Onekakara, as well as the septaria found in it, and he described the cone in cone structure which surrounds many of them. He also points out the difference between the Moeraki septaria and the ferruginous concretions of Kartiki, and mentions the occurrence of coal at Shag (Matakea) Point. The fossils he sent to England were examined by Dr. Mantell, Professor Morris, and Professor Rupert Jones, who referred the Ototara limestone, with doubt, to either the eocene or the cretaceous periods, while the Onekakara clay they considered to be pleistocene.

The next publication was a short paper in the Quarterly Journal of the Geological Society for 1855, by Dr. C. Forbes, of H.M.S. "Acheron," which ship had been engaged in surveying the West Coast sounds and Stewart Island. Dr. Forbes mentions that the mountains in the centre of the Province are composed of crystalline and metamorphic rocks, but that the former appear on the coast only in the extreme south and south-west. These rocks on the West Coast are described as "granitic rocks of various kinds—gneiss, mica-slate, hornblende rock, &c." The Bluff Hill, Stewart Island, and Ruapuke, are described as almost entirely composed of "blue-colored granitic rock containing hornblende in the place of mica." Dr. Forbes also mentions the "flesh-coloured granite" at Preservation Inlet, and was the first to describe the coal that occurs there and on Coal Island.

In 1859, Professor Huxley described † some bones of a whale,

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* So named by Mr. Mantell.

† Quarterly Journal of the Geological Society, 1859, p. 670.

and of a gigantic species of penguin, found by Mr. Mantell in the Ototara limestone, at Oamaru.

In January, 1862, Dr. W. Lauder Lindsay delivered a lecture in Dunedin, on "The place and power of Natural History in colonisation," in which he mentions the volcanic rocks of Dunedin, Saddle Hill, &c. He was the first to mention the evidence of former "glacier or ice action" in New Zealand, but he mistook decomposed lava streams near Dunedin for boulder clays. He considered the sandstones of Green Island and Caversham to be either tertiary or upper cretaceous. He was also the first to point out that the gold of Otago was derived from the mica-schists, which he compared to the rocks of the Grampians, in Scotland, and considered them to be of lower silurian age. He also noticed that the rocks between Tokomairiro and the Clutha, were different from the schists. He divided the auriferous drifts into two series, the older of which included the lignite beds, and he stated his conviction that "gold mining is destined to become one of the regular, permanent, industrial resources of Otago."

He was also the first to describe the true nature of the Otago lignites or brown coals, and mentions the coal fields of Saddle Hill, Green Island, Tokomairiro, and Clutha, and the lignite deposits of Waitahuna and Weatherstone's Flat.

In October, of the same year, he read a paper "on the geology of the gold fields of Otago" to the British Association, which however appears to have been a *resume* of his lecture.

Meanwhile, the Provincial Government determined, in 1861, upon having a geological survey made of the Province, and Dr. Hector arrived in Dunedin as Provincial Geologist, in April 1862, and he engaged as assistant geologists, Mr. Williams and Mr. Davis, and subsequently Mr. Hacket

The first report, by Dr. Hector, was on the geology of the Manuherikia Valley, and was published in the Provincial Government Gazette, of September 3rd, 1862. In this report, he describes the schists of the interior, and confirms Dr. Lauder Lindsay's opinion that they are the rocks from which the gold has been derived. He also points out the main anticlinal curve running in a N.W. by W. direction, and describes the interior basins, the contents of which he arranges under the heads of older and newer tertiaries.

"The older tertiaries," he says, "are the deposits which gradually filled up the depression as it passed through the successive stages of submergence, from an estuary-like arm of the sea to a deeply excavated submarine valley. They invariably consist at the base, where they rest on the schist, of strata which indicate the neighbourhood of dry land at the period of their formation, supporting a vigorous vegetation which has been preserved to us as brown

coal, associated with finely assorted beds of clay and gravel, indicative of current action in shallow water. Elsewhere, in the Province, marine shells have been discovered along with these beds. Over this group have been deposited strata of sand and conglomerate, formed of materials derived from the schistoze rocks. . . . The period of the greatest depression of the land, which corresponds with the close of what I term the older tertiary epoch, was marked in some districts of the Province by volcanic eruptions, during which basaltic lava was poured forth from rents in the earth's crust, and flowed over what were then the lowest levels of the sea bottom, but which have now, owing to the preserving influence of the hard tough basalt, become elevated to lofty positions.

"It was with the first display of volcanic activity, that the elevation of the land commenced, and although, as is always the case, this elevatory movement was accompanied by degradation of pre-existing strata, rather than by the formation of new deposits; yet under favourable circumstances, this very degradation gives rise to local deposits, which are those that I shall provisionally term the newer tertiaries.

"During this period the rock-bound basin, afterwards to be drained by the Taieri and Molyneux rivers, became converted into a system of lakes, connected by streams, which slowly excavated terraces, and deposited in a more perfectly assorted form the materials which compose the plateau. . . . As the main exit channels of the basin were deepened, the lakes were in time drained, and the materials again assorted by the erosion of the streams."

Dr. Hector's next report was the narrative of his "geological expedition to the west coast of Otago," in the schooner "Matilda Hayes," which was published in the Provincial Government Gazette of the 5th November, 1863. This report, although chiefly confined to a narrative of the expedition, contains many interesting and valuable notes on the geology of the district. He describes the geology of Bluff Hill, but calls the rocks "dark-grey felstone," "syenitic and felspathic gneiss," and fine grained-granite." He describes the basalt and limestone, at the base of the Longwood range, and the limestone of the Waiau, and he identifies them with those of Oamaru and Caversham. He also makes several remarks on the rocks of the Takitimu mountains, and Mt. Hamilton, incorrectly however, identifying the conglomerates of the latter with those of the Horse range, and the rocks of Howell's point with those of the Nuggets. Notes will also be found on the rocks of Port William and Paterson's Inlet in Stewart Island, and of the following sounds on the west coast, which, owing to unfavourable weather, were the only ones that he was able to visit. Preservation Coal Island: Chalky Inlet, including Edwardson and Cunaris Sounds; Thompson Sound, Secretary Island, and Crooked Arm; Milford Sound, and Anita Bay and Martin's Bay.

In the report there are also many suggestive notes, bearing on the surface geology of the country, most of which I shall subsequently quote, and in it Dr. Hector is the first to give good evidence of the former great extension of the glaciers in Otago.

In 1864, Dr. Hector, in his departmental report, gave a large amount of information about the coal fields of Otago. All of this, however, will be found reproduced in a more convenient form in one or more of his subsequent reports. In this year also, Dr. Hector produced a manuscript geological map of Otago and Southland, which was the first geological map ever attempted of the Province. The original map is in the Otago Museum, and a copy exists in the Colonial Museum at Wellington, but as it was never published, it will be only necessary for me to remark that it differs materially from the map that accompanies this report.*

The same year saw also the publication of Prof. von Hochstetter's Geology of New Zealand†, which, although not containing any new information on the geology of Otago, is important to us as containing the first systematic attempt at drawing up a table of the New Zealand formations, based on an examination of the fossils.

This is as under :—

Post tertiary and recent formations.
Younger tertiary strata.‡
    Hawke's Bay Series—Wanganui beds, &c.
    Awatere—Waitaki, Moeraki.
Older tertiary strata.§
    Waitemata beds.
    Raglan and Aotea limestones, &c.
    Coals of Drury, Waikato, and Motupipi.
Lower Cretaceous Group.
    Waikato, South Head, and Kawhia.
    Coal Fields of the West Coast of Nelson.
Jurassic group.
    Waipara beds.
    Amuri beds.
    Shaws Bay series.

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* In his lectures on mining in New Zealand (Trans. N. Z. Inst., ii. p. 373,) Dr. Hector refers to a map in the Otago Museum, which gives full details of the pleistocene geology of the district between Lake Wakatipu and the West Coast. This map I have never seen, and it is not now in the Otago Museum. The only map of this district in the Museum is a physical one, partly by Dr. Hector, and partly by Mr. J. M'Kerrow, which shews the bush and open country, but without giving any geological details, or the positions of moraines, &c. This is the map to which Mr. M'Kerrow refers in his paper on the physical geography of the Lake Districts of Otago, (Trans. N. Z. Inst., iii., p. 256), and which Dr. Hector, in a footnote on the same page, states to be entirely by himself, and to be partly reproduced in the map that accompanies his lectures on mining.

†Reise der Novara Geologischer Theil, i. Band, i. Abtheilung, Wien 1864.

‡ Oligocene or Upper Eocene. § Pliocene.

Triassic group.
Maitai series.
Richmond sandstone.
Palæozoic formations.
Slate ranges of the North Island and Southern Alps.
Metamorphic strata.
Schists of Otago and West Coast of the South Island.

In 1865, Dr. Hector published in the Quarterly Journal of the Geological Society of London (p. 124, &c.), a short paper on the geology of Otago, in which are embodied the results of his two year survey of the Province. This valuable paper is up to the present time the only attempt at a sketch of the geology of Otago as a whole that has appeared. In it he gives an ideal section from the west to the east coast, and divides the rocks as follows:—

I. Recent.
1. Alluvial. River-silts, shingles, and deltas,
2. Lacustrine. Exposed by the gradual drainage of lakes.
3. Estuarine or Littoral. Exposed by emergence of coast-line.

II. Pleistocene. (Newer gold-drifts.)
1. Lacustrine. In basins in the interior.
2. Glacial. Moraine-deposits and loess.

III. Pliocene. (Great gold-drift.)
1. Sand, &c., in basins in the interior (with lignite),
2. Coastward deposits.
a. Volcanic and tufaceous deposits.
b. Sands and clays.

IV. Miocene.
1. Oamaru or calcareo-arenaceous series.
2. Moeraki or argillaceous series (with brown coal).
3. Waitaki. Arenaceous.

V. Carbonaceous series. Estuarine strata, with conglomerates, sandstones, shales, and brown coal of fine quality.

VI. Te Anau series. Porphyritic conglomerate, wacke, claystones, glossy slates and diabase, and porcellanite

VII. Kaihiku series. Quartz, clay-shales, sandstone, diorite-slate, black cross-cleaved slate, siliceous and true clay-slate.

VIII. Foliated schists.
1. Grey argillaceous. Kakanui series.
2. Blue clay-slate. Micaceous or chloritic
3. Contorted felspathic schist.
All these are more or less impregnated with infiltrated quartz, and are auriferous.

XI. Gneiss-granite. Quartzose with garnets, or felspathic.

The Te Anau series he considers to be lower mesozoic, and the Kaihiku series to be metamorphic rocks "of not very ancient date." The carbonaceous series, he says, is either of tertiary or of upper mesozoic age. This is what he afterwards (1868) called the cretaceo-tertiary formation. The great difference between these two classifications is that Dr. Hector makes a great break in the sequence between the lower mesozoic and upper mesozoic or tertiary rocks, while Prof. von Hochstetter acknowledges no such break. The other errors in Dr. Hector's classification are that (1) the Moeraki series are placed below the Oamaru series, although Mr Mantell had previously assigned them their true position; (2) The "carbonaceous series" is made to include not only the cretaceous rocks of Shag Point, but also the jurassic rocks of the Mataura and Waikawa, which in reality fill up the break in his classification. (3) The Te Anau series are placed above instead of below the Kaihiku series; and (4) the granite of the West Coast is included with the gneiss in a "gneiss-granite" formation.

In the same year, Dr. W. L. Lindsay read a paper on the tertiary coals of New Zealand to the Royal Society of Edinburgh. In 1866 appeared the Jurors' Reports and Awards of the New Zealand Exhibition held in Dunedin in 1865. This contains a list of minerals found in Otago, and a valuable report (Appendix A) by Dr. Hector and Mr W. Skey, analytical chemist to the Geological Survey of Otago, on the coals, building stone, and minerals of New Zealand, of which I have made great use in the section on Economic Geology in this report.

In the same year Dr. Hector, who had been appointed Director of the Geological Survey of New Zealand, and had removed to Wellington, published a report on the coal deposits of New Zealand, which, however, does not treat of the geological position or age of the coal deposits.

In 1868, a paper was read to the Philosophical Society of Wellington, by Mr. J. Buchanan, Draughtsman to the Geological Survey of New Zealand, "on the geology of the country between the Lower Clutha and Mataura Rivers." But this paper appears never to have been published; at any rate I have never seen it.

In the Colonial Museum Report for the same year, Dr. Hector makes some remarks on the coals from the Hokanui Hill and Morley Creek, in Southland, but he here again falls into the error of considering the coal of Otapiri and Waikawa as belonging to the same formation as the coals of the West Coast, and he confounds the eocene coal of Morely Creek with the 30 foot seam of lignite of pleistocene age on the Mataura.

In 1869, Dr. Hector read a paper to the Wellington Philosophical Society "on the geology of the outlying Islands of New

Zealand,"* in which he remarks on the rocks obtained by Mr. Pearson, from Stewart Island, that they consist of "granite, gneiss, mica slate, felstone slate, and other crystalline metamorphic rocks, associated with granite-porphyry, diorite, and syenite" [*Ibid.* p. 185]. In the same volume [l. c. p. 361] Dr. Hector also published, under the title, "on mining in New Zealand," an abstract of four lectures delivered by him in July and August, 1869, at the Colonial Museum. In this interesting paper he gives a summary of the geology of New Zealand, dividing the rocks into two large divisions, one including the palæozoic and lower mesozoic eras, which he considers "represents groups from the upper silurian to the triassic periods"; and the other including the upper mesozoic and tertiary eras," which, from "the occurrence," he says—"of secondary cephalopods and saurian reptiles in the lower groups, render it probable that the strata range from jurassic formations upwards." This break in the sequence is evidently intended to be between the "carbonaceous series" and the "Te Anau series" of his former classification. He also mentions [p. 364] that his "gneiss-granite formation" of the West Coast extends to Stewart Island.

In the same volume Mr. C Traill has a paper "on the tertiary series of Oamaru and Moeraki," in which he correctly contends for the miocene age of the blue clay of Moeraki (Onekakara) as against the pleistocene or pliocene age assigned to it in Mr. Mantell's paper.

During this year also, Dr. Hector, in his Progress Report of the Geological Survey of New Zealand, 1868-9, notices the Mataura district, Southland, Preservation Inlet, Longwood Range, and Southern gold fields in general. In this report he states that the coal bearing formation of the Hokanuis "corresponds in age with the coal measures of New South Wales," and again, that "this formation corresponds in age with the upper part of the carbonaceous series of Australia, and below it in regular sequence the Otapiri section shows an immense thickness of lower secondary strata." So that he here, in opposition to his lecture on mining delivered the same year, takes the coal formation of the Mataura from his "carbonaceous formation," and places it with his lower mesozoic strata, upon which it lies in regular sequence. He also includes the Morely Creek coal with the coal-bearing beds of Shag Point, and those of the Buller and Grey River, with those of Nelson, Waikato, and Bay of Islands in his "cretaceo-tertiary" formation, which he says "in some respects must be considered as intermediate between the chalk and lower tertiary formations."

He also, in this report, states that in the Longwood Range there is "a repetition of the leading features of the Coromandel Peninsula, where the Thames diggings are situated."

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* Trans. N.Z. Institute, II. p. 176.

In this year also Dr. Hector published (although it was not issued until 1871) a geological map of New Zealand, with sections, in which the rocks are thus divided.

Pleistocene,
Upper Tertiary,
Cretaceo-Tertiary,
Lower Mesozoic and Upper Palæozoic
Lower Palæozoic,
Crystalline.

This is the only Geological Map of New Zealand as yet published. In it the geology of Otago is altered in several particulars. The Morely Creek coal is placed in the upper tertiary formation instead of in the cretaceo-tertiary, and the cretaceo-tertiary formation is made to include not only the Shag Point and Preservation Inlet series, but also the Otapiri, Mataura, and Waikawa series, which he had the same year identified with the coal measures of New South Wales. Even the Shaw's Bay series and Kaihiku series which up to this time Dr. Hector had regarded as upper palæozoic are now included in the cretaceo-tertiary formation. The general geology, however, of the Province, and the position of the lower palæozoic and crystalline rocks, is shewn with tolerable accuracy.

In 1870, Dr. Hector, in his catalogue of the Colonial Museum, Wellington, published another classification of the fossiliferous rocks of New Zealand, as follows:—

Post tertiary.	A.—Raised beaches and alluvial deposits.
Tertiary.	B.—Upper or Struthiolaria beds.
	C.—Middle or Cucullæa beds.
	D.—Lower or Ototara series.
Mesozoic.	E.—Leda marls or Aotea series.
	F.—Chalk or Cobden series.
	G.—Ferruginous Sandstones or Waipara beds.
	H.—Green Sandstones or Putataka beds.
	I.—Otapiri series.
	K.—Wairoa series.
	L.—Maitai series.
Palæozoic.	M.—Kaihiku series.
	N.—Mt. Arthur series.

This classification, founded on an examination of the fossils in the Colonial Museum, is a great improvement upon his former ones. But he includes the Aotea series with the mesozoic instead of the tertiary rocks, although its true age had long before been made out by Professer Hochstetter and Dr. Zittel. The nomenclature also is not well adapted for general application throughout New Zealand, as it is chiefly founded on mineralogical or palæontological considerations, none of which are specially characteristic.

During this year three papers were read to the Otago Institute on the geology of the Province. The first was by L. O. Beal, Esq.,

"On the deposition of the alluvial deposits on the Otago Gold Fields," in which he discusses the origin of the terraces in the inland plains, and contends for an almost complete ice cap having extended not long ago over the whole of Otago from the inland lakes to Dunedin. The second was by Mr. P. Thomson, "On the sand hills or dunes in the neighbourhood of Dunedin;" and the third was by J. McKerrow, Esq., "On the physical geography of the lake districts of Otago," in which he adopts a glacier origin for our inland lakes.

In 1872 I was sent by Dr. Hector to examine the Southland district, and the results I arrived at were published in the Geological Survey Report for 1871-2 (p. 89-112). These have been embodied in the present report. Towards the close of the year I also published in the same volume a synopsis of the younger formations in New Zealaand, as follows* :—

Pleistocene period.	Raised beaches, &c.
Pliocene period.	Newer pliocene or Wanganui group.
Miocene period.	Upper miocene or Awatere group. Lower miocene or Kanieri group.
Oligocene period.	Upper oligocene or Hawke Bay group. Lower oligocene or Waitemata group.
Eocene period.	Upper eocene or Ototara group.
Cretaceous period.	Danien or Waipara formation.

Dr. Hector published in the same volume a report on the Clutha and Green Island Coal Fields, which is founded on his departmental report to the Provincial Government of Otago, in April, 1864.

In the same year Dr. Hector read a paper to the Wellington Philosophical Society on the fossil penguin (*Palaeeudyptes antarcticus*, Huxley), from the West Coast of Nelson, and from Kakanui, in Otago. In this he gives a grouping of the strata to which he has "collectively applied the term cretaceo-tertiary, as no well-marked break that is common to all the sections that can be inspected has been observed in their sequence; and moreover certain fossil forms are found in all the members of the series."† In this he now includes as the upper beds, greensands and limestones, characterised by *Pecten hochstetteri*, "which represent the Ototara series," and in this view Dr. Haast concurred in 1873.‡ It is from these beds that the fossil penguin was obtained, and in 1870 and previously Dr. Hector had always considered them, with Prof. Hochstetter, to be tertiary, even miocene. So that between 1869 and 1872, the omnivorous cretaceo-tertiary formation is made to include sometimes triassic, and sometimes miocene rocks.

* This was also published, with additional information, in the Quar. Jour. Geol. Soc.

† Trans. N. Z. Institute, v. p., 344.

‡ Reports of Geological Explorations during 1872-3, iii. pp. 13 and 17.

In this year, also, Dr. Haast was sent to report on the Shag Point Coal Field, and the results of his examination will be found, partly in the Geological Survey Reports for 1871-2, and partly in those for 1872-3.

In 1873, I read two papers to the Wellington Philosophical Society, one "on the date of the last great glacier period of New Zealand," which I referred to the older pliocene period; and the other, "on the formation of Lake Wakatipu." During the same year I also published in Wellington, a catalogue of the Tertiary Mollusca and Echinodermata in the Colonial Museum, unfortunately without figures. In this I corrected my previous classification of the tertiary rocks to the following.

Probable Age.		
Newer Pliocene	Wanganui formation	
Upper Miocene	Pareora formation	{ Awatere group { Kanieri ,,
Lower Miocene	Ahuriri formation	
Upper Eocene	Oamaru formation	{ Trelissic ,, { Ototara ,,

In 1874 a paper was read to the Otago Institute by J. T. Thomson, Esq., "On Glacial Action in Otago," in which he contended that Otago formerly possessed a climate like that of South Victoria Land at the present day, and that the whole island was then enveloped in a sheet of moving ice, glaciers projecting out to sea in all our valleys. In the same year, I published in the Geological Magazine a table of the sedimentary rocks of New Zealand, which had been drawn up for the use of the geological class in the Otago University. This table I need not reproduce, as it is, with two exceptions, identical with the classification followed in this report. The exceptions are (1) that I now consider the Matai and Wairoa formations as one; and (2) that I have given Dr. Hector's name of Kakanui series precedence to my name of Tuamarina formation, which latter, therefore, now sinks to the rank of a synonym.

In this year also Dr. Hector, in his annual report of the New Zealand Institute, says that the fossils obtained by Mr A. McKay from the Nuggets and Catlin's River "serve to prove the existence in that district of a range of formations from lower jurassic to upper carboniferous."* And further on he says that

* All these are coloured as cretaceo-tertiary in his geological map of New Zealand.

"the general results obtained [by a comparison of the coal formations on both sides of the South Island] will also require a revision of the present classification of the lower tertiary strata, as the evidence and re-establishment of a cretaceo-tertiary formation, having for its upper member a representative of the nummulitic limestone."

It will thus be seen that the classification of the New Zealand rocks is in a very unsatisfactory state, which, it is hoped, this present report may in some degree help to clear up. But until the large collection of fossils which Dr. Hector has taken home with him are described by palæontologists in England, we cannot expect that many of these questions will be definitely settled.

SECTION III.

General Geological Structure.

The West Coast range of mountains, as far inland as Lakes Te Anau and Manipori, is composed of the oldest known rocks in New Zealand, which consist chiefly of gneiss and syenetic gneiss. At both extremities of the range a belt of slates, of the upper palæozoic age, wraps round the gneiss, and at Chalky and Preservation Inlets both the gneiss and slates have been broken through by a mass of eruptive granite, which occupies an extensive area in this district.

The oldest gneiss formation (Manipori formation) appears to be separated from the rocks to the eastward by an immense fault (see Sec. I.) : but at present this cannot be fully proved.

Eastward of this supposed fault, that is to say, in the whole of the country between the Waiau and the Waitaki, the rocks are thrown into broad folds, the axes of which run north and south in the north part of the Province, but gradually sweep round to the north-west and south-east, and dip slightly to the south-east, or away from the highest mountains. The main anticlinal axis (fig. 1.A)

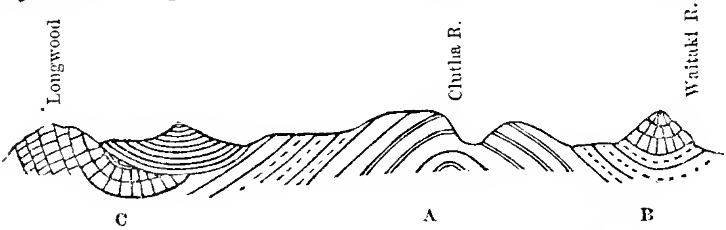

Fig. 1.—Generalised section across Otago :—A. Main anticlinal curve ; B. Northern synclinal curve ; C. Southern synclinal curve.

starts from between the Shotover and Lake Wanaka, and crossing through the Carrick and Knobby Ranges, passes north of Waipori to Outram and Saddle Hill. To the north-east a synclinal curve (fig. 1. B.) runs from the Ahuriri Pass in a south-east direction through Mt. Domett, and along the northern slopes of the Kakanui Mountains (Sections I. III. and IV.) to the Horse Range ; while south-west of the main anticlinal another synclinal (fig. 1. C.) runs from the Greenstone River (Section I.) through the Hokanui Mountains to Catlin's River (Sec. V.)

It will be thus seen that the main part of the Province of Otago is formed by a central anticlinal curve running in an approximate north-west and south-east direction, with a parallel synclinal

trough on either side of it. All the rocks of precretacous age take part in these curves, but the tertiary rocks are quite independent of them, and lie, when viewed on a large scale, horizontally, with only local varying dips.

The main anticlinal curve brings up to the surface a broad band of the older mica schists (Wanaka formation), which is the principal gold-bearing formation in New Zealand, and consequently it is along this band that most of the gold fields are situated. On either side of the anticlinal the mica schists are followed by a newer schist formation (Kakanui formation), which also contains gold in many places. Owing to the south-easterly dip of the anticlinal axis, that has been already mentioned, this newer schist formation wraps round the older mica schists on their south-eastern boundary, and the latter disappear below the younger rocks before reaching Dunedin. (Sec. II.)

On either side, again, the newer schist formation is overlaid by a mass of sandstones and slaty rocks of upper palæozoic age, (Kaikoura formation) which, under ordinary circumstances does not contain gold in payable quantities, but may do so exceptionally, as at Orepuki. In the northern synclinal (Fig. 1 B), these slates are the youngest rocks seen, the newer schists rising up again below them towards the Waitaki (Sec. III.), but a band of upper cretaceous rocks (Waipara formation) with coal, rests on the northern slopes of the Horse Range, and reaches the sea at Shag Point (Sec. VI). In the southern synclinal (Fig. 1, C) however, these slate rocks are followed by conglomerates and sandstones of triassic and jurassic age. These rocks form the Wairaki, Moonlight, and Hokanui hills, and extend down to the sea between the Mataura and Port Molyneux. More to the south-west, the slate rocks (Kaikoura formation) again come up to the surface, forming the Bluff Hill, Longwood Ranges, and Takitimus, and extends in a narrow band, which runs west of Lake Wakatipu, to Martin and Big Bays (Sec. I). Further to the westward neither of the schist formations have as yet been observed, but the slates appear to overlie directly the gneiss formation, previously mentioned as composing the West Coast Range (Sec. I).

Round the coast, where the older rocks have been worn away by the sea, patches of tertiary rocks, sometimes containing thick beds of coal, are found. These younger rocks extend in some cases far up the river valleys, as in the Waitaki, Shag River, Pomahaka, Oreti, and Waiau, where they reach to Lake Te Anau. A small patch also still remains on the east side of Lake Wakatipu, shewing that at one time they must have been far more widely spread than at present.

Volcanic action in tertiary times was chiefly developed in the neighbourhood of the east coast, the district around Dunedin Harbour, having been the principal seat of activity. But volcanic

rocks are found in the interior at Hamilton and Hyde, and in the south at Mount Pleasant; and other localities may probably exist, which have as yet escaped notice.

It will be seen from this general sketch that there is very little relation between the outward form of the ground and its internal geological structure. The highest land in the Province, from Mt. Aspiring through Mt. Earnslaw to Mt. Christina, crosses the strike of the rocks, and each of these mountains is situated in a different formation. Both schist and slate rocks form equally high mountains in the interior, and equally low and rounded hills near the coast. And it will be found that the shape and altitude of the hills is of no assistance in mapping the boundaries of all formations that are of pre-tertiary age.

Nearly all the rivers and lakes run obliquely or directly across the strike, the principal exceptions being the rivers in the north, such as the Hollyford, Dart, Shotover, and Lake Wanaka, all of which lie in the direction of the strike of the rocks.

Te Anau is the only lake that has different formations on its east and west sides. The difference in aspect here is striking, but it is caused by one side of the lake being composed of soft tertiary clays, and the other of hard gneiss, in a somewhat similar manner to Lake Geneva. The tertiary rocks are usually easily recognised at a distance, but I have in Otago ridden over a hill composed of tertiary sandstone without even suspecting that I had left the palæozoic slates.

Of the twelve different marine formations which, according to my views, are found in New Zealand, only one (Ahuriri formation), is altogether absent from Otago, and that belongs to the tertiary era. One other, however, of the tertiary formations (Wanganui formation), is not represented by marine rocks, but only by lacrustine deposits. So that the Province of Otago not only presents us with an almost complete epitome of the geology of New Zealand, but the structure of the district is so simple that it offers unequalled facilities for making out correctly the main features of its geological structure.

In the following table, which exhibits these formations, together with their probable age, I have thought it best to include all the known New Zealand formations, distinguishing that not found in Otago by printing it in italics; for to understand properly the geology of the Province it is nearly as important to know what formations are absent, as to know what are present:—

TABLE OF SEDIMENTARY FORMATIONS.

Probable Age.	Name of Formation.	Remarks.
Quaternary—		
Recent	Recent deposits	
Pleistocene	Pleistocene deposits Newer glacier deposits (*a*)	
Tertiary—		
Newer Pliocene	Wanganui formation (*b*)	Marine beds absent in Otago.
Older Pliocene	Older glacier deposits (*c*)	
Upper Miocene	Pareora formation* (*d*)	
Middle Miocene	*Ahuriri formation*	Absent in Otago
Lower Miocene	Oamaru formation* (*e*)	
Secondary—		
Upper Cretaceous	Waipara formation (*f*)	
Lower Jurassic	Putataka formation (*g*)	
Triassic	Maitai formation* (*h*)	
Palæozoic—		
Carboniferous (?)	Kaikoura formation* (*i*)	
Upper Silurian (?)	Kakanui formation (*k*)	
Lower Silurian (?)	Wanaka formation (*l*)	
Eozoic—		
Laurentian (?)	Manipori formation (*m*)	

The letters (*a*, &c.) refer to the sections, and to Plate II.
* Contemporaneous eruptive rocks are found in these formations.

The most important points in the geology of New Zealand, on which the Province of Otago can throw considerable light, are the following:—

1. The true position of the Spirifera beds (Maitai formation), and their relations to the formations above and below them.
2. The relations between the Wanaka, Kakanui, and Kaikoura formations.
3. The relation between the Waipara and Oamaru formations.
4. The date of the granitic and syenite outburst.
5. The date of the metamorphism of the Schist rocks.
6. The age of the propylites of Dunedin Peninsula.
7. The date of the last great glacier period in New Zealand.

SECTION IV.

Descriptive Geology.

Manipori Formation.

Distribution.—This formation is found only on the west coast, from Milford Sound to Preservation Inlet, extending inland to the Hollyford River, the Te Anau and Manipori Lakes, and to the upper part of the Waiau.

Rocks.—It is composed chiefly of syenetic gneiss, made up of white and yellow felspars with some quartz, and imperfectly foliated with hornblende and yellow or black mica. Sometimes the hornblende preponderates and occurs in layers or bunches, in which case mica is absent and the felspar is always white. Sometimes it passes into a dark grey gneiss, finely foliated with black mica, and at the head of Bligh Sound red gneiss occurs. At Milford Sound syenetic gneiss, containing numerous large crystals of red garnet, is found; and at Resolution Island and Bligh Sound there is a true garnet schist, composed almost entirely of granular garnets with layers of quartz. At Breaksea Sound granulite occurs composed of fine-grained white quartz with some felspar, and small flakes of black mica scattered through it in parallel planes. Hornblende schists foliated with small quantities of quartz, and hornblende rock, in which the quartz is absent, are common at Anita Bay aud Milford Sound, and the latter also occurs at Doubtful Inlet. Marmolite, or serpentine schist, is found at Anita Bay, and quartz schist at Deas Cove in Thompson Sound. There is also in the museum a specimen of mica schist, composed of black and yellow mica in large scales, foliated with quartz, which was brought by Dr. Hector from Seal Island. Cipollino, a white granular limestone, with an internal coarsely crystalline structure, and with numerous flakes of pink lithia-mica scattered irregularly through it, is found in Thompson's Sound, and the same rock, but with little or no mica, occurs at Anita Bay.

Position of strata.—At the entrance to Wet Jacket Cove, between Dusky and Breaksea Sounds, the rocks are vertical, and strike north and south. In Shoal Cove, at the head of Bradshaw Sound, the dip is N.W., at a high angle. In Thompson's Sound, the dip is about 45° N.W., and in the south fiord of Te Anau Lake, 67° N.W. In Milford Sound, opposite Harrison's Cove, the dip is 80° W.N.W., and at Anita Bay it is 75° W. by S.

Thickness.—It will be thus seen that the dip is remarkably uni-

form throughout, and the formation must be of enormous thickness. The distance from the entrance into Thompson's Sound to Lake Te Anau is about 40 miles, and I observed the dip to be N.W. at both ends and in the middle of the section, and never at a less angle than 45°. This would give a thickness to the formation of at least 160,000 feet, which appears to be incredible, but we can only escape from this conclusion by supposing either that I happened to make all my observations on similar sides of synclinal curves, which is quite possible, or that the plane of foliation does not correspond with the original plane of bedding for which at present there is no evidence.

Age.—Although these rocks are separated from the other metamorphic rocks in the centre of the Province by a band of slates and sandstones, their more highly metamorphic character is sufficient evidence that they are older than the mica schists of the Dunstan (Wanaka formation), for I shall presently shew* that this extreme metamorphism cannot be accounted for by the presence of the granite at Preservation Inlet, and consequently we cannot be very far wrong if, for the present, we consider them as belonging either to the Laurentian or to the Cambrian period.

Eruptive Rocks.—A considerable number of dykes and veins of eruptive rocks occur in this formation, but it is uncertain at what period they were erupted, and some of them may be due to segregation. *Vein granite*, generally fine grained with white felspar, quartz, and black mica occurs at Milford Sound,† and Seal Island;‡ and Titiroa, a high mountain behind Manipori Lake appears to be composed of a dyke of white granite. *Pegmatite*, consisting of coarsely grained white felspar and quartz, with silvery white mica, occurs at Milford Sound. *Mica Trap*, composed almost entirely of black mica in coarse flakes with some layers of felspar, was brought by Dr. Hector from Petrel Island, in Dusky Bay, in 1863; as also was a *chlorite porphyry*, consisting of a white felspathic matrix, with yellow mica and green fissile chlorite, from Seal Island. *Eurite*, composed of white felspar and quartz, occurs at Wet Jacket Cove and Milford Sound; and *Porphyrite* at Milford Sound.

Minerals.—The Serpentine which occurs plentifully at Anita Bay, is pale green, translucent and with a more or less schistose structure. It is tolerably hard, but can be scratched with a knife. It is the inferior greenstone, or Tangiwai, of the Maoris, and the Marmolite of mineralogists. The true greenstone, or Poumamou of the Maoris,—the Nephrite or Jade of mineralogists—appears to occur only in veins through the marmolite, and

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* See Maitai formation, contemporaneous eruptive rocks.

†Specimens brought by Dr. Hector. ‡ For further remarks on this point, see Section V, *Eozoic and Palæozoic Eras.*

does not exist in large separate dykes. Nephrite may be distinguished from Marmolite by its hardness, it being impossible to scratch the former with a knife. Chemically, nephrite differs from marmolite only by the absence of water in its composition, and any number of different varieties may be found differing much in hardness, even in the same block of marmolite.

This formation is remarkably barren of metalliferous veins. No gold in anything like a paying quantity has been found in any alluvia derived from it, but Dr. Hector has reported silicate of copper from Milford and Bligh Sounds, and cobalt bloom from some other locality not named.*

Nomenclature.—I have given the name of Manipori formation to these rocks, as the Manipori Lake is situated entirely in them. It is the same as the Gneiss-granite formation of Dr. Hector.†

Wanaka Formation.

Distribution.—This formation extends in a broad belt, some 40 miles in width, through the centre of the Province. Commencing on the northern boundary, between Mt. Aspiring and Lake Hawea, with a breadth of 30 miles it gradually expands southward, embracing the lower half of Lake Wakatipu, the Dunstan district, and the valley of the Clutha River as far south as the Beaumont Ferry, when, turning to the eastward, it terminates before reaching the sea between Outram on the south, and the head of the north branch of the Waikonaiti River on the north, but appearing again on the beach at Brighton. Thus occupying an area of about 5000 square miles.

Rocks.—It is composed almost entirely of mica-schist, ranging from an argillaceous mica-schist, as at the Carrick Ranges, to a gneiss-like looking rock, as in the neighbourhood of Bendigo. Ordinarily, it is composed of very fine silvery-grey mica foliated with quartz, and it often has a waved or corrugated structure. Near Queenstown chlorite-schist is largely developed. At Mt. Alta, near Lake Wanaka, there is a quartzose-mica schist, composed of pinkish quartz and fine scales of mica in regular parallel foliæ,‡ and in the Shotover a remarkable looking hornblende-schist is found, composed of irregularly foliated quartz and hornblende in about equal quantities; and as the hornblende often occurs in needle-shaped crystals lying across the plane of foliation, it gives the rock an appearance somewhat similar to that of graphite granite. Large crystals of iron-pyrites are found in this rock.

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* N. Z. Exhibition Jurors' Reports and Awards, p. 265.

† Quar, Jour. Geol. Soc, 1865, p. 128, ix. (*k*).

‡ This description is taken from a specimen in the Museum. I have not seen the rock in situ myself.

One of the chief characteristics of the rocks of this formation is the numerous laminæ of pure white quartz, of considerable thickness generally found in them. This is no doubt the effect of extreme metamorphism, from which has resulted the entire separation into distinct layers of all the superabundant silica that was distributed through the rock previous to metamorphism.

Corrugations.—The remarkable corrugation of much of the schist is not so characteristic of these rocks as the separation of the quartz into layers, for it is also occasionally found in the next (Kakanui) formation. These corrugations are generally supposed to be owing to the original rock, previous to metamorphism, having contained ripple marks, it being supposed that the foliæ have followed the curves of the ripple mark in the same way as they follow the planes of lamination or of cleavage. But although this explanation may account for the phenomena in some places, it can hardly do so in Otago, partly because many of the corrugated rocks have evidently been clays which never carry ripple-mark, and partly because the corrugations, as seen in the beautiful sections in the Shotover, cover one another so accurately and regularly, though more than 20 feet in thickness, that it is impossible to suppose they can owe their origin to ripple mark, which is always irregularly distributed through a rock. I think a better explanation can be found in the expansion by heat of soft rocks under great vertical pressure; the compression thus produced having been relieved by numerous small corrugations, instead of by fewer and larger contortions.

Position of Strata.—These rocks, although so old and so much metamorphosed, lie remarkably flat over their whole extent. They form, as has been already mentioned, a low broad anticlinal curve, rising to the north-west, and running through the province, but branching off at the Upper Taieri into two anticlinals, one running to the Waikouaiti Downs, and the other to Hindon, with a flat synclinal between them running from Sutton Stream to Blueskin Bay (see Sec. III). Thus on the southern and western side of the anticlinal, the rocks dip in the Shotover from 15° to 25°, N.W. to S.W; at Skipper's, the dip is 30° to 50°, W.; at Five Mile Creek, 40° S.W.; at Queenstown, 25° to 45° S.S.W.; and at Kingston, it is 15° S.W. Further south the beds curve round more to the east, and the dip at Waipori is 25° S.S.E.; and at Outram, 35° S.S.E. On the north-east side of the anticlinal, the dip at the south end of Lake Wanaka is 40° N.E.; in the neighbourhood of Bendigo, from horizontal to 35° N.N.E.; and at Black's, 10° N.E. Along the top of the anticlinal, the dip is variable, but generally to the south-east. For example, at the bridge in the Kawarau Gorge, it is 40° S.S.E.; at Clyde, 25° S.E.; at Alexandra, 20° S.E.; up the Conroy, 10° S.S.E. On the other hand the dip is very variable in the Carrick Ranges, and in the Dunstan Gorge it varies from 25° W.

to 28° S.W. Towards the east, where the main anticlinal splits up into two, the dip between the Lees and Deep Stream, is very slightly N.N.E.; in the Deep Stream it is 15° N.N.E, and in the Upper Sutton, slightly E.N.E. But at the lower end of Strath Taieri, the dip is 10° S.W.; and it again becomes north at Hyde and McRaes.

Foliation.—As the changes in the lithological character of these rocks take place at right angles to the plane of foliation, it follows that the foliation coincides with the original plane of bedding. This is further confirmed by the general geological structure of the district, for, as a general rule, the plane of foliation dips towards that portion of the next younger formation that lies nearest. The same might also have been inferred from the small angle of inclination that these schists have over a large extent of country. For if the foliation had taken place along planes of cleavage, it would have had the high angles of inclination which usually accompany that structure, due to the cleavage planes having been formed at right angles to pressure laterally applied.

Relation to underlying formation.—It has been already mentioned that no junction can be found in the Province of Otago between this and the Manipori formation; consequently it is impossible to say whether there is any unconformity between the two. This may perhaps be proved in Westland, as both the Manipori and Wanaka formations are stated to extend into it.*

Thickness.—As the base of this formation is not exposed it is impossible to ascertain its thickness, but it is certainly very great, for between the Arrow River and Moke Creek it cannot be less than 50,000 feet. Its probable age will be better discussed after the two next formations have been described, for the rocks have undergone so much metamorphism that it is hopeless to expect that we can ever find fossils in them; although as plumbago has been found in the Dunstan and Wakatipu districts, it is evident that vegetable remains were once entombed in them.

Eruptive Rocks.—The almost entire absence of eruptive rocks in both this and the next formation is remarkable, and very difficult of explanation. I know but one small dyke of porphyrite in the Carrick Ranges.

Minerals.—It is however the main gold-bearing formation of Otago. Quartz mines are being worked in it in the Shotover and Arrow Rivers, at Bendigo, in the Carrick Ranges, and at Waipori, while the gold obtained from most of the alluvial workings has also been derived from the degra-

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* Hector, Geological Map of New Zealand, 1869; and Haast, Notes on the geology of the central portion of the Southern Alps. Reports of geological explorations, 1870-1, p. 23, and sections Nos. 9 and 10.

dation of these rocks. Copper exists at Moke Creek and Carrick Ranges. Cinnabar has been found near Waipori, at the Dunstan, Carrick Range, and Serpentine Valley. Silver has been found at Lake Wakatipu,* and in the Kawarau Gorge. Galena is reported from Rough Ridge and Tokomairiro. Antimony is found at the Arrow, Carrick Ranges, and other places. Rhodonite in the Kawarau Gorge, and scheelite at the head of Lake Wakatipu, and in the Shotover and Arrow Rivers. Impure graphite occurs in considerable quantities in the Carrick Range, where, according to Mr. Buchan, it is sometimes 13 feet thick.

Nomenclature.—As this formation has not yet received a name I have called it the Wanaka formation, for it surrounds Lake Wanaka on both sides. It is identical with the "contorted felspathic schist" of Dr. Hector.†

KAKANUI FORMATION.

Tuamarina Formation (Hutton).

Distribution.—This formation extends in an almost continuous belt round the western, southern, and eastern margins of the Wanaka formation. Commencing in the Forbes Mountains, north of Lake Wakatipu, it includes the northern half of that lake and, passing between Kingston and Athol, it bends gradually to the east to form the northern portions of the Garvie and Umbrella Mountains. East of the Pomahaka it is interrupted by an overlapping of the Kaikoura formation in the Tapanui, or Blue Mountains, but appears again on the eastern side of the Clutha, forming the southern part of the Tuapeka gold fields from Gabriel's Gully to Mount Stuart and Waihola Lake. On the north-eastern side of the Tokomairiro Plain it re-appears, forming the low hills near the sea from the Akatore River to Saddle Hill. From the latter place a narrow band runs northward, forming the Chain Hills, until it disappears under the basalts of Flagstaff Hill. Commencing again north of the Taieri Plain, it forms the southern part of the Silver Peak Mountains, and runs out to a point at the south-west corner of Waikonaiti Harbour. Commencing again in the Shag Valley, it runs in a north-westerly direction, and gradually increases in breadth until it covers the country from Hyde and Hamilton to the Kakanui River, including a large part of the Kakanui Mountains. Further to the north-east a small detached portion is found at Awamoko. North of the Kakanui Mountains it splits into two bands, one of which runs north to the Waitaki River at Kurow, and the other runs north-west through Kyeburn Hill, Mount Ida, the Hawkdun Ranges and Blackstone

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*First discovered by J. B. Bradshaw, Esq.

† On the Geology of Otago. Quarterly Journal Geological Society 1865. p. 128, viii., 3 (i').

Hill, Dunstan Peak, Mount St. Bathans, and the Upper Lindis, to the north-east corner of Lake Hawea.

Rocks.—The principal rock composing this formation is a grey phyllite, or argillaceous mica schist, in which the mica is but very feebly developed, but beds of clay slate, mica schist, and occasionally of quartzite, also occur.

Position of Strata.—At the head of Lake Wakatipu the rocks belonging to this formation dip 65° S.W. on the east side, and 15° S.S.W. on the west side of the lake. At Fews Creek the dip is 45° to 60° W. East of Athol the dip is 45° E.S.E., but more to the west it alters to W.N.W. In the Upper Pomahaka I observed the dip to be 50° to 70° N.E., which shows some irregularity in the structure of this district. In the neighbourhood of Lawrence the general dip is southerly, but the lay of the rocks is not uniform. I observed here one dip of 30° S.E., and others from 10° to 20° S.W. At the head of Weatherstone's Gully it is 25° S.E. At Saddle Hill the dip is 20° to 30° W.S.W., but in the tunnel through the Chain Hills it varies considerably, being 50° E.N.E. on the west side, and 35° to 43° S. by E. on the east side, and it is probable that the southern branch of the main anticlinal passes between the tunnel and Saddle Hill. In the north-east part of the province the dip is much more regular, being at Morven Hill Station and Lindis Pass 45° N.E., at St. Bathan's 45° N.E., at Mount Ida 30° N.E., and at Hamilton 5° to 17° N.N.E. North of the northern syncline the dip at Kurow is 45° W. At Maruawhenua the beds are vertical, with a S.E. by E. strike; at Awamoko they dip 50° S.W., and in the Otepopo district the dip is pretty constant to the west and south-west.

Relation to underlying formation.—This formation is quite conformable to, and passes insensibly into, the Wanaka formation. The distinction between them is quite arbitrary, and I should not have attempted to separate them if it had not been necessary to divide such an enormous thickness of rocks in order that the map might display somewhat of the geological structure of the district. But the difference between them is simply owing to the older and lower formation having undergone more metamorphism than the upper.

Thickness.—The thickness of this formation can be estimated far more accurately than either of the two former; for in the Upper Lindis the rocks dip pretty steadily at an angle of 45° for a distance of 14 miles. This would give a thickness to the formation of 10 miles, or 52,800 feet.

Fossils.—In my report on the geology of the north-east district of the South Island,* I stated that some obscure fossils had been found near Picton in a blue argillaceous sandstone belonging

* Reports of Geological Explorations 1872-3, p. 31.

to this formation, but Dr. Hector has since informed me that a a considerable number of fossils have been lately obtained from this locality by Mr. A. McKay, and that some of them are identical with tertiary fossils in the Colonial Museum; so that at present no fossils have been found in these rocks, although they may probably exist in some of the clay slates. If found they will, I expect, prove to be identical with the graptolites, &c., of the auriferous slates of Victoria.

Eruptive rocks.—I know of no eruptive rocks in this formation, except some tertiary basalts which will be mentioned further on in the report.

Minerals.—Gold is generally distributed through this formation, but not so abundantly as in the last. The richest diggings where the gold has been exclusively derived from these rocks is at Naseby, for the alluvial deposits worked at Nokomai, Switzers, Tuapeka, Hamilton, &c., have been in great part derived from the Wanaka formation.

Nomenclature.—This formation is identical with Dr. Hector's Kakanui series*, and also with the Tuamarina formation of my report on the geology of the north-east district of the South Island†, and as that name was given by me, because at the time I was not able to identify it with Dr. Hector's Kakanui series, I now abandon it and revert to Dr. Hector's previous name.

Kaikoura Formation.

Te Anau Series—Hector (?).

Distribution.—The principal mass of this formation extends southward from Big Bay and Martin Bay on the West Coast through the valleys of the Hollyford and Greenstone Rivers, and the Livingstone and Eyre Mountains to the Dome. From there it trends south-eastward across the Upper Waikaka to the Tapanui Mountains, and from there down the Lower Pomahaka and Clutha to Stony Creek. It is again found forming the northern base of Mount Misery and the hills north of the Tokomairiro River, between the plains and the sea. Another branch goes southward, forming the Takitimu Mountains, and then again divides into two, the westerly branch going through Black Mount and the Monowai and Howloko Lakes to the sea coast, between Te-wae-wae Bay and Chalky Inlet, while the eastern branch forms the Longwood Ranges, the Bluff Hill, and the northern part of Stewart Island, each of these being isolated from one another by tertiary rocks or the sea. Whether this formation extends through Stewart Island I cannot say, as I have never been south of Port William.

* Quar. Jour. Geo. Soc., 1865, p. 128, VIII. 1 (*i*).

† Reports of Geological Explorations, 1872-3, p. 31.

In the north of the province these rocks are again found in the valley of the Ahuriri River, as far as the Waitaki, and they extend south through the Kurow Mountains. Another narrow patch occupies the hollow of the northern synclinal, and forms the southern part of the Kakanui Mountains, and the northern part of the Horse Ranges.

Rocks.—The rocks composing it are principally argillite, clay slate, and grey sandstone, or quartzite, with occasional beds of jasperoid-slates and conglomerate. In the Horse Ranges two bands of a very fine-grained granular marble are found, which is of a grey colour, with streaks of white running through it in all directions, and is of a subschistose structure. Port William, in Stewart Island, is composed of slates and sandstone, dipping 70° W., and intersected by numerous dykes of syenite and granite. Rugged Island is principally quartzite, dipping 55° W. Codfish Island I did not visit, but the rocks brought me from there show that it is composed of quartzite, conglomerate, and phyllite. Dog Island is formed of slates and conglomerate, but I could not satisfy myself as to their dip.

Position of strata.—At the Bluff the rocks are more or less vertical, the dip changing from 75° N.N.E. to 85° S.S.W. At the Narrows, near Riverton, the beds are also vertical, with a S.E. strike. Between Lake Wakatipu and the Hollyford River the rocks of this formation, which commence just above the natural bridge in the Route Burn, dip about 25° N.W. In the Leithen, which flows from the Umbrella Mountains into the Pomahaka, the dip is 35° S.E., and in the Upper Pomahaka 62° S.S.E.; in the Waipahi 75° S. At about three miles north-west of Clinton the dip is 25° S.S.W., and at Stony Creek 25° to 40° S.E. by E. In the northern part of the province I was not able to ascertain the dip in many localities, but at Mount St. Cuthbert it appears to be 40° N.W., and in the Horse Ranges it is 25° N.E. by E.

Relation to underlying formation.—That an unconformity exists between the Kaikoura and the Kakanui formations is evident from an inspection of the map. Along its western boundary the Kaikoura formation rests upon the Manipori formation, and wraps round it both at Martin Bay on the north and Preservation and Chalky Inlets on the south. At the Tapanui Mountains it overlaps the Kakanui formation, and rests partly on the Wanaka formation, while the patch of Kaikoura rocks in the Horse Ranges must also lie unconformably on the Kakanui formation, as there is not sufficient room for the whole of the latter to come out between the former and the Wanaka formation on the opposite side of the Shag Valley. It is not so easy to prove this in actual sections, but I believe that I came across a case of unconformity in the cutting leading down into the valley of the Pomahaka on the road from Dunrobin. The upper part of this cutting consists of argillites,

which I take to belong to the Kaikoura formation, and which appear to dip 62° S.S.E.; but, as is usual in this formation, the bedding is not very distinct. The lower part of the cutting is in phyllites, belonging undoubtedly to the Kakanui formation, and dipping 50° to 70° N.E., but the two portions of the cutting are divided by a space of more than 100 yards, along which no rocks can be seen.

Metamorphic Action.—Notwithstanding this unconformity, it it is by no means easy, in the absence of fossils, to draw the line between these two formations; for the metamorphic action has passed upwards through both, assimilating to some extent along their boundary the rocks of each formation. The gradual transition from true mica and chlorite schists to ordinary slate, or argillite, as we ascend from the Wanaka to the Kaikoura formations is certainly not due to any of the intermediate phyllites being "recomposed" rocks; but shows a gradual diminution in metamorphic action from below upward. The evidence here seems to me to be strongly against the views advocated by Sterry Hunt, Favre, and others, that the crystalline schists were originally deposited in their present form.

Thickness.—I have no data to estimate the thickness of this formation in Otago, but it is not so well developed as it is in the northern part of the South Island.

Age.—Notwithstanding that this formation is widely spread from one end of New Zealand to the other, no fossils have as yet been described from it, but it has always been considered as palæozoic both by Dr. Hochstetter and Dr. Hector, and as it underlies quite unconformably the Maitai formation, which is of lower jurassic or triassic age, we may consider it for the present as belonging to the carboniferous period, and the Kakanui and Wanaka formations to the upper and lower silurian periods respectively.

Fossils.—In my report on the geology of Southland I described some fossil remains from Coal Hill and Centre Hill as belonging probably to the Foraminifera,* but I am indebted to my friend Professor Rupert Jones of the Staff College at Sandhurst, to whom I sent specimens, for correcting my mistake, and pointing out to me that they are weathered fragments of the shells of *Inoceramus* or *Perna;* consequently I have removed these rocks from the Kaikoura into the Maitai formation.

Contemporaneous Eruptive Rocks.—Thick masses of green stone (aphanite) tuff are found interbedded with the slates and sandstones in the valleys of the Route Burn, and Greenstone near Lake Wakatipu, and also in the neighbourhood of Long Ridge near the Waimea Plains. Dykes of various eruptive rocks also occur in many places, but as there is reason to think that they

* Reports of Geological Explorations 1871-2.—p. 103.

belong to the Maitai formation I shall consider them under that head.

Minerals.—Gold in small quantities is found throughout this formation, but the Longwood Range is the only place in which it occurs to any considerable extent. The gold of the Orepuki district must have come out of these rocks, as it is found up the valley of the Waimeamea, a small river rising in the Longwood Range. The conditions here are eminently favourable for the existence of metallic ores, as the slate rocks have been much penetrated by igneous dykes; and the same favourable conditions extend to the northern part of Stewart Island, and to the country between Te-wae-wae Bay and Preservation Inlet.

Nomenclature.—I consider the rocks here described to belong to the Kaikoura formation of my report on the geology of the north-east district of the South Island.* They cannot be the same as the "Kaihiku series" of Dr. Hector,† as neither the Kaihiku Mountain nor the valley of the Kaihiku River are composed of them. They may possibly belong to his "Te Anau series,"‡ for in some respects his section agrees very well with their position; but if so, the name is unfortunately chosen as nearly as the whole of the shores of Lake Te Anau are formed either of gneiss belonging to the Manipori formation or of tertiary rocks. Dr. Hector also considers his "Te Anau series" as lower mesozoic, and compares it with the porphyritic rocks in South America,§ to which the present formation does not bear the slightest resemblance. So that altogether I am unable to identify Dr. Hector's "Te Anau series" with any rocks in Otago, and consequently I think it best that this formation, which is widely spread from Stewart Island to the North Cape, should go by the name of the Kaikoura formation until it is divided up more into detail.

Maitai Formation.

Kaihiku series, (Hector?); Wairoa series, (Hector); Richmond sandstone, (Hochstetter); Otapiri series, (Hector); Shaw's Bay series, (Lauder Lindsay).

Distribution.—This and the next formation are only found filling the southern synclinal already described.‖ Commencing north of Burwood, near the heads of the Mararoa and Oreti Rivers, it runs in a south-easterly direction; forming Coal Hill, Centre Hill, Mount Hamilton, the Wairaki Downs, the Moonlight Ranges, and the northern portion of the Hokanui Hills. Here it disappears under the Putataka formation, but reappears again in the Kaihiku

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* Reports of Geological Explorations, 1872-3, p. 32.

† Quar. Jour. Geol. Soc., 1864, p. 128, vii. h.

‡ l. c. vi. g.

§ l. c., p. 124.

‖ *Ante* p. 23, Fig. 1, C.

Hills, running down to the Nuggets on the sea coast, and spreading north beyond the road from Balclutha to Clinton. Twinlaw and Bald Hill, lying north of the Longwood Range, also appear to belong to this formation.

Rocks.—The rocks are principally shaly slates, argillites, and green sandstones, with occasional beds of conglomerate and greenstone tuff. These conglomerates consist entirely of subangular fragments of slate and sandstone, and I have never found a single pebble of any eruptive rock in them.

Position of Strata.—Along its north-west margin, this formation is very much disturbed, being thrown into several bold plications. At Mount Hamilton, the dip is 40° to 65° E.; at Centre Hill, 50° W. by S.; and at Coal Hill, (a south-westerly spur from the Eyre Mountains,) it is 75° E. by N. Along the southern part of the Wairaki Hills, near the head of the Morely Creek, the dip is 20° N.E.; and at the gorge, where the river enters the plain, 15° S.W. At Castle Rock Station, on the north side of the Moonlight Range, the dip is 20° S.W.; while further south, near Dipton, it is 30° S.S.W. On the eastern side of the Oreti River, above Benmore, these rocks dip 20° S.S.W.; and on the northwest side of the Hokanuis, in the bed of the Waimea Stream, 60° N.E. by E.; while at the head of the Otapiri, they are vertical; and strike south-east and north-west. At Popotunoa Gorge, the rocks dip S.W. at high angles, to vertical; but between Clinton and Balclutha, the dip seems to be generally northerly, and in the Waitepeka I found it to be 55° N. At the Nuggets, these rocks are vertical, and strike N.W. and S.E.

Relation to Underlying Formation.—The junction between this and the last formation is not very clear in the Province of Otago, and I have not been able to find a section showing it resting on the rocks of the Kaikoura formation. But that it does do so is evident from the general geological structure of the district, and from the much less amount of metamorphism that these rocks have undergone, than those of the Kaikoura Formation. In the Clutha district, there appears to be an uniformity between the two, but it is not well marked. In the Province of Nelson, however, complete unconformity exists, as I have elsewhere pointed out.*

Thickness.—I am unable to give any estimate of the thickness of this formation on account of the foldings along its northern border, which will require very careful surveying to unravel; but it is certainly more than 15,000 feet.

Fossils.—At Coal Hill, a southern spur of the Eyre Mountains, and at Centre Hill, near Mount Hamilton, fragments of the shell of a species of *Perna* or *Inoceramus* are found in considerable quantity, but I found no specimen sufficiently perfect to shew the shape

* Geological Reports, 1872-3, p. 34.

or exterior sculpture of the shell. On the eastern slope of the Moonlight Range, on the spur of a hill about four miles north of Lipton Station, beds composed almost entirely of *Monotis salinaria* var. *Richmondiana* Zitt. and *Halobia lomelli* Wissm. occur, and at this spot I also obtained a longitudinally ribbed *Mytilus*, and an imperfect cast of a species of *Perna*. I was also informed that the same fossiliferous rocks are found on the hills to the north-west of Castle Rock. On the opposite side of Oreti River, at a place called Cowan's Wash, I obtained *Monotis*, *Halobia*, a large ribbed species of *Pecten*, and many plant remains; and from the railway cutting in the neighbourhood, *Spirigera wreyi* Suess, and two species of *Spirifera* have been forwarded to the Museum. One specimen of *Spirifera* shews well the spirally rolled lamella that supports the arms. At Morely Creek, on the south side of the Waikari Hills, I got *Halobia*, and casts of *Isocardia*, *Trochus*, &c., and Dr. Hector reports *Inoceramus* and *Trigonia* from the same locality. At Omaru Creek, between Catlin's River and the Clutha, Professor Black obtained *Monotis salinaria*, *Pecten*, and others; and at Shaw's Bay, or Roaring Bay, near the Nuggets, *Spirifera* and other fossils not yet described were found by Dr. Lauder Lindsay. Dr. Hector also found *Spirifera*, &c., in the Upper Otapiri, and Mr. J. Buchanan collected *Halobia*, *Spirifera*, &c., from the gorge of the Kaihiku River. Two of these fossils are analagous to, or even specifically identical with those of the Alps of Salzbourg: while *Spirigera wreyi* is, according to Dr. Zittel, most nearly related to the devonian *Spirigera undata* Defr.

Age.—No formation in New Zealand has suffered more ups and downs in the geological scale than this, although as it contains fossils identical with species in Europe, and determined by a European palæontologist, it might have been thought that its true position could be ascertained with greater accuracy than any other of our formations. In 1864 it was referred by Professor von Hochstetter and Dr. Zittel to the triassic period. In 1866 Dr. Hector classed the rocks of the Nuggets, and Kaihiku Range as upper palæozoic.* And he repeated this in 1870 in his catalogue of the Colonial Museum. But in his geological map of New Zealand, published about the same time, he colored them "cretaceo-tertiary." Dr. Haast has always considered rocks in Canterbury, which contain the same fossils as these, to be of lower carboniferous, or devonian age; and Dr. Hector in his last report of the New Zealand Institute (1874, p. 564), says that some of the rocks at the Nuggets belong to the carboniferous period, thus agreeing with Dr. Haast. On this point I may remark that *Inoceramus* or *Perna* occurs in the lowest beds of the series, and below *Monotis* and *Halobia*; while the two latter are found below the *spirifera* beds, and at the Omaru Creek *Monotis salinaria* occurs in beds that certainly

* N. Z. Exhibition Jurors' Reports and Awards, p. 265.

do not overlie those exposed at the Nuggets. When to this we add that reptilian remains (*Ichthyosaurus australis,* Hector,) are found associated with the same species of *Spirifera* at Mr. Potts in Canterbury, we have little doubt but that this formation is not older than the trias. The question will I hope soon be settled, as Dr. Hector has taken a large collection of these fossils to England with him in order that they may be described there, meanwhile I agree with Hochstetter and Zittel in referring them to the triassic period.

Contemporaneous Eruptive Rocks.—In Preservation and Chalky Inlets a considerable area is composed of a coarse-grained pink granite, which I consider to belong to this formation. This granite consists of a matrix af red orthoclase and white quartz with small quantities of black mica, and is clearly eruptive and younger than the slates and sandstones of the Kaikoura formation which it pierces, and pieces of which are often seen enveloped in the granite. Fig. 2 represents a junction of the granite with slate on the east side of Isthmus Sound in Preservation Inlet. The junction here is quite abrupt and jagged, and two angular fragments of slate are seen embedded in the granite. The slate near the junction has been considerably altered, and converted into a finely crystalline rock of a dark grey color. The minerals are separated, and mica and quartz grains can be recognised with a lens, but microscopical investigation is necessary before the changse can be satisfactorily made out. This alteration, however, does not penetrate very far, and the great mass of the slates in the neighbourhood are quite unaltered. The felspar of the granite generally gets white as it approaches the slates, and for about an inch from the junction gets very fine grained, but the mica flakes increase in size. But in some cases the granite preserves its character close up to the slates. This proves clearly the eruptive nature of the granite, and that the eruption took place later than the Kaikoura formation. It also proves that the highly metamorphic character of the gneiss rocks of the Manipori formation is in no way owing to the granite outburst, as the granite has failed to alter the slate rocks in its immediate vicinity.*

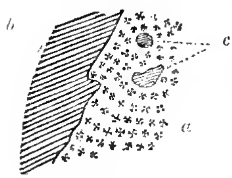

Fig. 2.—Junction of granite and slate, Isthmus Sound.—*a.* Granite; *b.* Slate (Kaikoura formation); *c.* Fragments of slate in granite.

I have already mentioned that in the conglomerates of the Maitai formation no pebbles of granite or other eruptive rock are to be found; but in the Putataka formation, next to be described, pebbles of this pink granite occur; consequently, the date of this granite must lie between the Kaikoura and Putataka formations. Further evidence of this is found in the numerous dykes of syenite,

*See *ante,* p. 28.

diorite, &c., that penetrate the rocks of the Kaikoura formation, some of which pierce the lower beds of the Maitai formation, as I shall presently mention; but not a single dyke is as yet known in the Putataka formation. I have also elsewhere* shewn that volcanic action was going on during this period in the Nelson Province, and I think therefore that we need not hesitate to connect the granitic eruption of Preservation Inlet, with the injection of dykes of syenite and greenstone, and probably also with the volcanic action, in the surrounding district.

In Preservation Inlet the granite extends from Revolver Bay and Isthmus Sound to beyond Lady Bay, but occasional masses of slate are found amongst it. Great Island, in Chalky Inlet, is also entirely composed of it. How far it extends up Long Sound, Cunaris Sound, and Edwardson Sound I do not know, as I have not been up them; and I have filled in this boundary on my map from the remarks on the rocks in Dr. Hector's narrative of his West Coast exploration. With the exception of a few veins, I saw no granite in any of the other Sounds that I visited, viz., Dusky Sound, Wet Jacket Cove, Breaksea Sound, Doubtful Sound, Bradshaw Sound, Thompson Sound, Bligh Sound, and Milford Sound; and I saw none on the west side of Te Anau Lake. At the Bluff Hill, a broad dyke of syenite, composed of white felspar and crystals of black hornblende, runs nearly parallel with the bedding of the slates, and the line of junction between the two rocks is very complicated, veins of syenite, isolated apparently from the main mass, appearing among the stratified rocks parallel with the bedding, and looking as if the syenite was here a product of metamorphism, and that the argillaceous rocks had been changed into syenite, while the more arenaceous ones had resisted the action; but these appearances are, I am satisfied, fallacious. This syenite sometimes passes into an almost pure hornblende rock; sometimes it is of a green color, caused by the dissemination of small particles of hornblende through the mass, but when exposed to the weather, these minute particles soon disappear from the surface, leaving the larger crystals studding the white felspar base with black spots. Several dykes of a similar rock are also seen at Port William in Stewart Island. Centre Island appears to be entirely composed of it, as also, Captain Fairchild informs me, is Ruapuke. Another dyke also occurs at the east end of Wakapatu Bay, at the base of the Longwood Range, and others probably in the Takitimus. On the east side of the Nuggets a dyke of grey porphyry, with white crystals of felspar, traverses the rocks of the Maitai formation at right angles to the bedding.

Nomenclature.—The fossils found in these rocks show that they are identical with the Maitai series of Professor Hochstetter. They may also be in part the Kaihiku series of Dr. Hector, as they

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* Reports of Geol. Exploration, 1872-3, p. 34.

form the Kaihiku Range. But this is uncertain, as Dr. Hector's description of the rocks forming his Kaihiku series does not at all agree with those at present under consideration, and he places it below his Te Anau series, which certainly cannot be my Putataka formation. In view of this uncertainty it is, I think, better to retain Professor von Hochstetter's name, which also has the priority.

In a former report on the geology of the north east district of the South Island, I separated the *Monotis* bearing beds from those with *Spirifera* and *Inoceramus* (?), under the name of the Wairoa formation; but a further examination of these rocks in Otago, where they are better displayed than in any other part of New Zealand, has convinced me that this distinction will not hold, and that all must be classed in one formation.

Putataka Formation.

Mataura Series of Lindsay and Hector.

Distribution.—This formation is confined to the Hokanui Hills and to the country lying between the lower Mataura and Cannibal Bay, near the Nuggets. But it is also seen in the beds of some of the creeks on the Seaward Downs, below the gravels.

Rocks.—The rocks composing it are slates, green and brown sandstones, shales, conglomerates, and thin seams of coal. At Benmore, in the Hokanuis, the conglomerates contain pebbles of a pale purple porphyry, with crystals of white felspar, like the dyke north of the Nuggets; and of pink granite like that at Preservation Inlet, as well as pieces of green, red, and blue slates, and quartz. At the north end of False Islet, near the mouth of Catlin's River, the conglomerates are formed of quartzite, sandstone, jasperoid slate, quartz, diorite, white granite, red porphyry with white crystals of felspar, and grey porphyry with white crystals of felspar.

Position of Strata.—Behind Benmore Station, at the west end of the Hokanuis, these rocks dip 20° E.S.E., and at Bastion Hill, where a splendid section is seen, 10° S.E. by E. In a south-easterly direction from this the beds get more horizontal, dipping in the Otapiri Gorge very gently to the north east. At the eastern end of the Hokanuis the dip is 30° S.S.W., and at the Mataura Falls 3° N.N.E. On the left bank of the Mataura River, below Wyndham, the dip is 10° N.N.W., and at the Toi-Tois 6° N.N.E. At Otaraia the dip is 35° S.S.W., at a high angle. From the mouth of the Mataura to Waikawa the rocks are nearly horizontal (See Sec. v.), but dipping slightly to the north. East of Waikawa the beds begin gradually to dip very gently to the north east, and this continues through Chasland's Mistake, to Tautaku and Hakkup Bays, from which the dip increases to Jack's Bay. On the south side of Jack's Bay the rocks again flatten, dipping here 8° N. On

the north side of the bay they are horizontal, rising again with a S.S.W. dip towards Catlin's River. (Fig. 3).

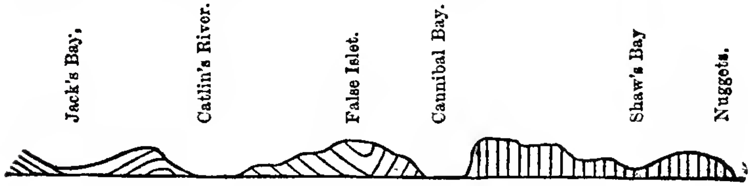


Fig. 3.—Jack's Bay to the Nuggets. Distance, 6 miles.

Jack's Bay therefore occupies a synclinal curve. The S.S.W. dip continues until close to the entrance to Catlin's River, when it changes sharply to the N.N.E.; the anticlinal running under the Pilot Station and Flagstaff. This direction in the lay of the rock is continued to False Islet, at the south end of which the dip is 50° N.E. False Islet itself is formed by a synclinal curve, the northern side of which is so sharply thrown up that at the north side of the Islet the dip is 80° S.S.W.; while on the north side of Cannibal Bay the beds are vertical, and strike S.E by E. This vertical position of the strata is maintained through Roaring or Shaw's Bay to the Nuggets, where the strike is S.E. and N.W. The rocks of the Putataka formation extend, I consider, to a little beyond the north point of Cannibal Bay, where they are followed quite conformably by the rocks of the Maitai formation.

Relation to Underlying Formation.—I was formerly of opinion that an unconformity existed between this and the Maitai formation, but the evidence I adduced, viz., different strikes in neighbouring localities,* is not of much weight, and I have since examined the coast section betwen Catlin's River and the Nuggets, and find that the two are quite conformable. The formations here can only be distinguished by their fossils.

Thickness.—I estimate that the thickness of these rocks in the Catlin River district is between 9,000 and 10,000 feet.

Fossils.—From Bastion Hill I obtained in 1872 a small compressed *Pholadomya* about an inch in length, and three-fifths of an inch in height, concentrically furrowed, and finely radiately striated; and from the tributary of the Otapiri in which coal has been found, I found a species of *Astarte*, apparently identical with *A. wollumbillaensis* Moore.† From Tautuku *Ammonites* and *Astarte* have been obtained, and at Jack's Bay I saw *Astarte* (?), *Ostrea*, and a species of *Mytilus* with a curved beak, perhaps *M problematicus* Zitt; and many fragments of wood. Fossil ferns, among which are *Polypodium hochstetteri*, and species of *Tæniopteris* are found at the Otapiri Creek, Seaward Downs, Mataura Falls, Waikawa, Owaike

* Reports of Geological Explorations 1871-2, p. 104.
† Quar. Jour. Geol. Soc, xxvi., p. 250, pl. xii., fig. 12.

Creek near Catlin's River, and the upper part of the Omaru Creek. These ferns have not yet been described, but many of them are no doubt identical with those found near Port Waikato.

Age.—In 1864 Professor von Hochstetter and Dr. Zittel referred the rocks at Port Waikato, which belong to this formation, to the jurassic period. In 1867, in my report on the Lower Waikato district, I called them Neocomian, and in the same year Professor von Hochstetter, in his "New Zealand," considered them as cretaceous. In his Progress Report of 1868-9, Dr. Hector considers that this formation "corresponds in age with the coal measures of New South Wales;" but in 1869 and 1870, he placed it in his "cretaceo-tertiary" formation, and in his report on the coal fields of New Zealand, in 1873, he calls it "upper secondary." In 1872, in my report on the geology of Southland, I referred it back again to the middle jurassic period, and I still think that it is either middle or lower jurassic.

Nomenclature.—These rocks have been called the "Mataura series" by Dr. Hector; but if, as I think, they are the equivalents of the Port Waikato beds, my name of Putataka formation, given in 1867, will take precedence.

Waipara Formation.

This formation is very feebly represented in Otago, as it occurs only in two localities.

Horse Range.—The first of these is situated at the mouth of the Shag River, and in the Horse Range, and extends in a northerly direction to the south branch of the Otepopo River, or Rookery. Here it is interrupted by the schist rocks, but further to the north an outlier crosses the north branch of the Otepopo River, and continues up to Island Creek.

Rocks.—The lower portion of this series is composed of shales and sandstones, with thin beds of inferior coal, and conglomerates which are formed chiefly of fragments of slate and sandstone. Above these, in the Horse Range, are thick beds of quartz conglomerates, which thin out seaward, and are covered by a series of conglomerates, sandstones and shales, with good seams of pitch coal. The uppermost beds of all are sandstones and sandy clays, with almost spherical ferruginous concretions, which have been commonly mistaken for septaria, and confused with the true septaria of Moeraki, which belong to a much younger formation.

Position of Strata.—The lower beds, where they abut against the slates of the Kaikoura formation, dip at about 25° N.E., at the highest point in the road from Palmerston to Moeraki; but as these beds wrap round the denuded edges of the palæozoic slates, the dip constantly changes. To the east, along the Shag Valley, the dip increases until it attains to 60° S.E. at Mount Ivitai, and then gradually increases again until it is about 20° S.E., at the mouth of the Shag River. Towards the north an anticlinal axis is passed,

and the beds dip more gently to the north-east, the angle of inclination at Shag Point, where the coal mine is situated, being about 6° N.E., and it decreases still more further to the north, where the beds containing ferruginous concretions reach the sea, and the beach is strewed with these rounded stone balls of all sizes, known as "Katiki boulders." Boulders, however, is not a correct term to apply to them, as it means a stone rounded by the action of water, while the spherical outline of the "Katiki boulders" is their original shape, they having been formed in the rock in which they are found by a chemical concretionary action, and have never been worn until washed out of their bed.

Fossils are scarce in these rocks, but several casts of bivalve shells have been obtained from the upper beds. These have not yet been properly examined, but they appear to me to be quite distinct from any found in the tertiary rocks. There is also in the Museum a fragment of an *Ammonite*, which is said to have come from this locality. Plant remains, especially leaves of dicotyledons, are more abundant; and a *Dammara*, which is not uncommon, has been identified by Dr. von Haast with one found at the Waipara associated with the remains of saurians. Dr. Hector in his catalogue of the Colonial Museum had previously classed these rocks with the Waipara beds.

Thickness.—I estimate the thickness of the Shag Point series to be between 6000 and 7000 feet.

MOUNT HAMILTON.—The second patch of rocks belonging to this formation is found near the summit of Mount Hamilton in Southland, at an elevation of 2,500 feet above the level of the alluvial plain of the Oreti, or about 3.700 feet above the sea.

Rocks.—The lowest bed of the series is a conglomerate, overlaid by shales with several seams of coal, which are again covered by yellow sandstone with thin seams of coal.

Position of Strata.—This series forms a synclinal curve (see fig. 4), the axis of which inclines downward to the S.W. by S., the

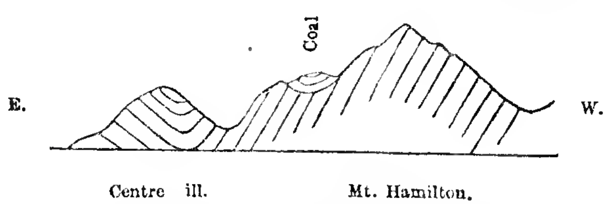


Fig. 4.—Mount Hamilton Coal Beds.

western portion dipping 25° S.E., and the eastern 30° W N.W.

Fossils.—The sandstones above the coal contain numerous impressions of leaves of dicotyledonous plants, many of which Mr. J. Buchanan informs me are identical with those from Pakawau, in the Nelson Province.

Relation to underlying formation.—Nowhere in Otago can a junction be seen between the Waipara and Putataka formations, but in the Nelson and Canterbury Provinces they are quite uncomformable. In the Horse Ranges the Waipara formation rests unconformably on both the Kaikoura and Kakanui formations (see Sec. VI.), and at Mount Hamilton it rests unconformably on the Maitai formation.

Age.—Professor Owen, in 1861, was of opinion that the beds from which *Plesiosaurus australis* had been obtained, were probably of jurassic age,* but Dr. von Haast in 1865, considered them as tertiary.† Speaking of this formation in 1869, Dr. Hector says, "I believe [it] corresponds with the wealden group of Britain, No. 6, [ferruginous clays and sands, with concretionary nodules containing saurian bones,] being the equivalent of the green sand." In my report on the geology of Southland, in 1872, I said that I was inclined to think that the Mount Hamilton beds would prove to be of upper cretaceous age,‡ and later in the same year, an examination of the fossils in the Colonial Museum, from the Waipara and Amuri, made me come to the same conclusion with regard to the Waipara formation.§ In the following year Dr. von Haast so far modified his opinion as to class them in Dr. Hector's "cretaceo-tertiary" formation, and Dr. Hector, when describing the Saurian remains‖ from Amuri and Waipara, refers them to the cretaceous period; to the upper part of which I think they undoubtedly belong. No recent mollusca are known from this formation.

Nomenclature.—The term Waipara beds was applied by Dr. Hector to this formation, in his catalogue of the Colonial Museum, 1870, and previously by Prof. von Hochstetter.

Oamaru Formation.

Ototara and Trelissick groups. (Hutton).

This formation is scattered about in patches in various parts of the Province, but principally near the coast.

Oamaru and Waitaki.—In this district the formation extends from the Kakanui River to the Waitaki Plains, and stretches inland up the valley of the Waitaki, as far as Kurow Creek. The lowest beds in the series are thin bedded dark sandstones, upon which lies the calcareous free-stone so well known as the Oamaru limestone. It is an earthy limestone, containing 90 per cent. of carbonate of lime, and is followed by a hard crystalline shelly lime-

* British Association Report, 1861, p. 122.
† Report of the Geological Explorations of the West Coast, Christchurch, 1865.
‡ Reports of Geological Explotations 1871-2, p. 184.
§ Reports of Geological Explorations, 1871-2, p. 184.
‖ Transactions N. Z. Institute, VI., p. 337.

stone. These constitute the Ototara group. Upon them rest quite conformably, calcareous conglomerate, containing fragments of slate and volcanic rocks, and green and yellow sandy clays, sometimes interstratified with volcanic rocks, the whole being again covered with limestone. These represent the Trelissic group. These beds lie, on the whole, nearly horizontal; for the rocks up the Waitaki are but little, if at all, higher than those at Oamaru; but the strata have various local dips. At the Awamoa railway cutting, beds belonging to the Trelissic group, dip 15° N.E., while in the valley of the Waireka, near Cave Valley, beds belonging to the Ototara group dip 5° E by North. Up the Maruawhenua, the beds are nearly horizontal, the lowest one visible being grey sandy clay, followed by calcareous sandstone, which is overlaid by a brownish red sandstone. Higher up the Waitaki there is an outlier of tertiary green sandstone, which appears to be capped by calcareous rocks. These probably belong to the Oamaru formation. Below them good brown coal occurs.

Otepopo.—Further to the south soft green sandstones, dipping to the east, are seen in the Otepopo River. These probably belong to the Trelissic group, but no fossils have as yet been found in them. They are overlaid by the dolerites of Mount Charles.

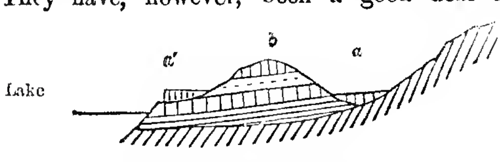
Shag Valley.—Grey, green, and yellow sandstone, associated with shelly beds, are found near Palmerston, and form the base of Puketapu, Mount Royal, Smyler's Peak, &c., where they are horizontal. But these beds are not very extensively developed here, and the boundaries of the different tertiary formations, are not easily made out. These rocks are again seen at Deepdell Creek, sixteen miles up the Shag River, from whence they extend pretty continuously to Pigroot. Here they consist of green sands, covered by calcareous sandstone and limestone, the whole being often capped by basalt. (See Sec. VI.) Still higher up green sands with marine fossils, belonging probably to this formation, are found in the Kyeburn Creek at the coal mines, lying in the Maniototo plains, at the base of the Kakanui Monntains. Some of the green sandstone in Shag Valley, contains small specks of alluvial gold.

Dunedin.—Still going south along the coast, the next place that these greensands are met with is at Merton, between Waikouaiti and Blueskin, and from here they appear to run in a narrow band at the head of the Waitati Stream, and west of Swampy Hill, to Flagstaff Hill, where they are cut off by the basalts which run from Flagstaff Hill down to Silver Stream. At the head of the Waitati the rocks are grey calcareous sandstone and bituminous shale. In the Valley of the Kaikorai the Caversham sandstone again appears, and runs through Look-out-Point to the sea. It is overlaid by basalt, and below it is a thick series of greenish gray sandstone and clays with brown coal, forming the coal series of Green Island and Saddle Hill. (See Sec. IX). A narrow belt of

these rocks runs across the Dunedin Peninsula, north of Harbour Cove, between Boat Harbour and Macandrew Bay, and appears again on the north side of Dunedin Harbour. The sedimentary rocks here consist of sandstone, and yellow and brown limestone, and are overlaid by the trachytes and basalts of Harbour Cove. The dark brown limestone, which contains about 87 per cent of carbonate of lime, overlies the yellow limestone, but I was unable to ascertain the position of the sandstones which are found on the Dunedin Harbour side of the Peninsula.

Tokomairiro and Kaitangata.—Again going south an isolated patch of limestone, belonging to this formation, is found on both sides of the road at Waihola Gorge, and still further south rocks of the same age are extensively developed between the Tokomairiro River and the Clutha, forming the Tokomairiro and Clutha coal field. These rocks consist chiefly of conglomerates, sandstones, and shales; but at Tokomairiro a black bituminous limestone occurs, which is said to overlie the coal.* During my visit to Tokomairiro I was not fortunate enough to find this limestone, although I made many enquiries about it, so that probably it is of very small extent. The conglomerates over the coal at Wangaloa contain alluvial gold.

Lake Wakatipu—At Fews, or Twelve-mile Creek, on the east side of Lake Wakatipu there is a small patch of tertiary rocks belonging to this formation. The lowest bed is blue shale covered by green sandstone, which is again followed by calcareous sandstone with bands of conglomerate, the whole being capped by a hard grey limestone, containing 90½ per cent. of carbonate of lime, and about 3 per cent. of carbonate of magnesia. These beds are about 600 feet thick, and dip 15° S.E., towards the Lake. (Fig. 5, B.) They have, however, been a good deal undermined, and large masses of the limestone have fallen down into the Lake, giving the western portions a very broken appearance I have also been informed that other outliers of this formation exist on the north side of Afton Burn, on the west side of the Lake, and up the Shotover in Stony Creek. Limestone boulders, with fossils, are also said to occur at Alexandra, but the rock has not yet been found *in situ*, and I do not know whether they belong to this or the next formation.



Limestone at Lake Wakatipu.

Fig. 5.—Limestone at Lake Wakatipu: *a*, river alluvium; *a′* lake terrace; *b*, limestone, &c., (Oamaru formation); *c*, schist (Kakanui formation).

* Hector, Cat. Col. Museum, 1870, p. 186.

Blue Spur, Tuapeka.—In this locality a small patch of conglomerates are found occupying the top of the ridge between Monro's and Gabriel's Gully. These conglomerates are formed of pebbles of quartz, green quartzite, dark purple jasperoid slate, and fragments of schist, bound together by a blue clayey matrix. They occupy a cup-shaped depression in the schist rocks, and dip to the east. (Fig. 6.) The reasons that lead me to think that these conglomerates are of eocene age, and therefore better arranged under the Oamaru formation than any other, will be better understood after the geological history of the Province has been discussed, and they will therefore be found in Section VI. I would, however, remark that if my views are correct, these conglomerates do not strictly belong to the Oamaru formation, but to a slightly earlier period.

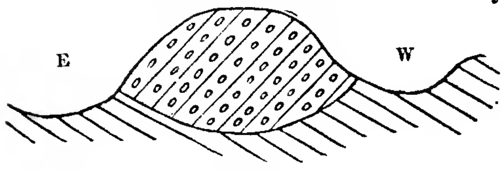


Fig. 6.—Blue Spur, Tuapeka.

Southland.—In the Southland district a patch of limestone belonging to this formation is found in the Waimea plains, between Longridge and the Mataura. This patch does not form hills and cannot be distinguished in outline from the flat-topped alluvial terraces of the plain. Another isolated patch forms a long, narrow strip of low hills, running in a N.N.W. direction from Forest Hill, near Winton, to Centre Bush Hill, on the Oreti River; and two other small outliers occur in the valleys of the Moonlight Ranges, one forming the picturesque Castle Rock, and the other a small hill north-east of Castle Rock.

Another and more extensive area is found on both sides of the Longwood Range, extending north as far as Sharp Ridge and the Wairaki Downs, along the south base of which it spreads from the Night Cap Hill to Taylor's Creek. It also crosses the Waiau River and probably covers an extensive district as far north as the Monowai River, but this country is but little known at present. Higher up another patch is found at Freestone Hill, near where the Waiau runs out from Lake Manipori. The Haycock Hills, also, between Centre Hill and the Mararoa, belong to this formation, and other patches may exist round the base of the Takitimus; but I have not been able to determine accurately the boundaries of the different tertiary formations in this district. At Orepuke, at the southern base of the Longwood Range, another small patch is found occupying the valley of the Waimeamea.

The rocks belonging to the Oamaru formation in Southland are principally shelly limestone and calcareous sandstone; but the Haycocks consist of blue fissile marls with calcareous bands, and reddish yellow sandstone. Round the base of the Wairaki Downs

the rocks are sandstone, micaceous sandstone, and shales with coal; and at Orepuki they are also shales with coal.

As in the northern part of the Province, the formation here must, when viewed on a large scale, be considered as nearly horizontal, but rising slightly to the north. Local dips are, however, very various. For example, at Castle Rock it is 10° N.N.W; at Lime Hill, near Winton, 30° S.E.; at Forest Hill, and in the Waimea Plains, the beds are nearly horizontal, but inclining slightly to the south-west; while on the northern base of Centre Hill the dip is 10° to 40° N.W.

Preservation Inlet.—On the south-west coast of the Province, rocks, probably belonging to this formation, extend in a narrow belt from Green Islets, past Windsor Point to Preservation Inlet, between Puysegur Point and Otago's Retreat. They also compose the greater part of Coal Island and Chalky Island, and are also found on the promontory between Preservation and Chalky Inlets. The rocks here are entirely sandstones and shales, with a few seams of coal, except at Chalky Island, where the upper beds are grits and and chalk-marl.

I could not observe the lay of the beds between Green Islets and Windsor Point, but at the latter place they dip 40° W., and going to the west a synclinal curve is seen opposite Marshall Rocks. (See Sec. X.) Further to the west an anticlinal curve occurs in the neighbourhood of Puysegur Point. At Otago's Retreat the beds dip 25° West, and this direction of dip is continued without much variation through Coal Island and Chalky Island.

As no fossils have as yet been found in these rocks, it is doubtful whether they should be referred to the Oamaru or the Waipara formation, but I place them here for the present principally on account of the large quantity of resin found in the coal, which is characteristic of our tertiary coals.

Relation to underlying formation.—No well defined junction between this and the Waipara formation is found in Otago, but at both places where the Waipara formation occurs the general geological structure of the country leaves no room for doubt as to the relations between the two. In the Shag Valley, the Horse Range, which is the leading physical feature of the district, is composed in large part of rocks belonging to the Waipara formation (Secs. VI. and VIII.), which must have been deposited before the Shag Valley was eroded out, as they form the northern water-shed of that valley. But rocks belonging to the Oamaru formation are found lying horizontally in the bottom of the Shag Valley (Sec. VI. and Fig. 8), which must, therefore, have been hollowed out previous to their deposition. A complete unconformity must, therefore, exist between the two formations here.

Again, at Mount Hamilton, the rocks belonging to the Waipara formation enter into the internal structure of that mountain, and

have evidently partaken in the latest disturbances on an extensive scale, that caused the New Zealand Alps (see Fig. 4); while the rocks belonging to the Oamaru formation skirt round the bases of these mountains, and fill up the old vallies, indicating evidently a considerable unconformity between the two. If also the Waipara formation formed the base of the Oamaru formation, as supposed by Dr. Hector, we should certainly somewhere in the Province find the former underlying the latter. But such is not the case, for although the Oamaru formation is extensively developed, in Otago it invariably, with one possible exception at the Otepopo River, rests directly on triassic or palæozoic rocks.

Thickness.—It is difficult to estimate approximately the thickness of this formation; but I think that between Saddle Hill and Forbury it cannot be less than 2,000 feet.

Fossils.—I am now acquainted with 88 species of mollusca from this formation, 12 of which (or $13\frac{1}{2}$ p. c.) I believe to be still living. Of these 88 species one only, *Cucullæa ponderosa,* is as far as I can judge, common to the Oamaru and Waipara formations. Dr. Hector takes a very different view to this, and holds that a large number of forms are common to both. When the collection of fossils taken to England by Dr. Hector are described, this point will be settled. The following list gives the names of all the fossils belonging to this formation that have been found in Otago :—

	Oamaru.	Waitaki.	Maruwhenua.	Puke Tapu	Shag River.	Caversham.	Green Island.	Waihola.	Tokomairiro	Waimea Plains.	Winton.	Moreley Creek	Lake Wakatipu.	Kyeburn.
MAMMALIA—														
Phocænopsis mantelli, *Huxley*	*													
Ziphius, *sp.*						*								
AVES—														
Palæeudyptes antarcticus, *Huxley*	*													
PISCES—														
Teeth of Carcharodon megalodon, *Owen*														
Teeth of Carcharias, *sp.* ...	*													
,, Lamna, *sp.* ...	*	*												
MOLLUSCA—														
Aturia, *sp.*	*				*									
Dentalium giganteum, *Sow.*		*											*	
,, solidum, *Hutton*														*
Fusus, *sp.*				*										
Pleurotoma hebes, *Hutton* ...	*													

	Oamaru.	Waitaki.	Maruwhenua.	Puke Tapu.	Shag River.	Caversham.	Green Island.	Waihola.	Tokomairiro.	Waimea Plains.	Winton.	Morely Creek.	Lake Wakatipu.	Kyeburn.
Voluta pacifica *Lam* var β				*										
,, ,, var γ	*		*		*	*								
,, corrugata, *Hutton*													*	
Volvaria ficoides, *Hutton*	*													
Natica ovata, *Hutton* ...	*													
Scalaria browni, *Zittel* ...	*													
,, lyrata, *Zittel* ...	*	*												
Struthiolaria senex, *Hutton*	*			*		*								
Turritella gigantea, *Hutton*	*			*		*								
Crypta striata, *Hutton* ...	*													
Parmophorus unguis, L. ...	*													
Panopæa plicata, *Hutton* ...													*	
,, worthingtoni, *Hutton*													*	
Pholadomya, *sp.*	*													
Tellina alba, *Quoy* (?) ...									*					
Unio inflata, *Hutton* ...												*		
Pinna distans, *Hutton* ...					*									
Cucullæa ponderosa, *Hutton*													*	
,, worthingtoni, *Hut.*		*											*	
,, alta, *Sow* ...		*					*		*				*	*
,, attenuata, *Hutton*						*							*	
Pectunculus laticostatus, *Quoy* ...	*			*		*								
,, globosus, *Hutton* ...	*													
Pecten williamsoni, *Zittel* ...	*													
,, fischeri, *Zittel* ...	*													
,, semiplicata, *Hutton*	*													
,, venosum, *Hutton* ...	*													
,, hochstetteri, *Zittel* ..	*			*	*	*				*	*			
,, hutchinsoni, *Hutton*	*										*			
,, beethami, *Hutton* ...	*													
,, ,, var β ...	*					*								
,, burnetti, *Zittel* ...	*									*	*			
,, polymorphoides, *Zit.*				*										
,, zitelli, *Hutton* ...						*								
Lima lævigata, *Hutton*† ...								*						
,, paucisulcata, *Hutton* ...						*								
,, palæata, *Hutton* ...	*													
Ostrea wullerstorfi, *Zittel* ...	*							*						
,, incurva, *Hutton* ...	*													

†This is the same as *Inoceramus macilentus* of my report on the Geology of the North-east portion of the South Island. (Reports of Geological Explorations during 1872-3, p. 43). I forgot to make the correction when publishing my "Catalogue of the Tertiary Mollusca and Echinodermata, in the Colonial Museum."

	Oamaru.	Waitaki.	Maruwhenua.	Puke Tapu.	Shag River.	Caversham.	Green Island.	Waihola.	Tokomairiro.	Waimea Plains.	Winton.	Morely Creek.	Lake Wakatipu.	Kyeburn.
BRACHIOPODA—														
Waldheimia lenticularis, *Desh*	*	*								*	*		*	
„ concentrica, *Hutton* ...	*													
„ triangulare, *Hutton* ...	*									*				
„ sinuata, *Hutton* ...	*													
„ gravida, *Suess* ...	*													
Terebratella gaulteri, *Morris*	*	*												
Rhynchonella squamosa, *Hut.*	*													
POLYZOA—														
Eschara, *sp.*	*													
Cercopora ototara, *Mantell*...	*													
„ *sp.*	*													
Manon, *sp.*	*													
CIRRIPEDIA—														
Pollicipes, *sp.*	*													
ENTOMOSTRACA—														
Bairdia subdeltoidea, *Münst*	*													
Cythereis interrupta, *Bosquet*	*													
„ gibba, *Rœmer* ...	*													
„ galtina, *Jones* ...	*													
ECHINODERMATA—														
Cidaris, *sp.*	*													
„ *sp.*	*						*							
Nucleolites papillosus, *Zitt*	*													
Hemipatagus formosus, *Zitt*	*									*				
Macropneustes spatangiformis, *Hutton*	*													
Amphidotus sulcatus, *Hutton*	*													
Brissiopsis alta, *Hutton* ...	*													
Meoma crawfordi, *Hutton* ...	*					*				*				
Shizaster rotundatus, *Zitt* ...	*													
FORAMINIFERA—														
Rosalina lævigata, *Ehr* ...	*													
„ beccarii, *G.* ...	*													
„ lorneiana, *D'Orb* ...	*													
Textularia elongata ...	*													
„ globosa, *Ehr* ...	*													
„ aecieulata, *Ehr*...	*													
„ *sp.* ...	*													
Globegirina, *sp.*	*													
Nodosaria limbata, *D'Orb* ...	*													
Cristellaria rotulata, *Lam.*...	*													
Dentalina, *sp.* ...	*													
Polymorphina, *sp.* ...	*													
Bulimina, 2 or 3 species ...	*													

Besides the foregoing leaves of dicotyledonous plants, and ferns are found in the sandstones up Linton Creek, and leaves are also found at Morley Creek, and Green Island.

Age.—In 1850, Dr. Mantell, Professor Morris, and Professor Rupert Jones, considered the Ototara limestone, from the few fossils sent to England by the Hon. W. Mantell, to be either eocene or upper cretaceous. In 1864, Dr. Hector referred it with doubt to the miocene period.* In 1865, Dr. Zittel and Dr. Stache, after examining the fossils taken to Europe by Professor von Hochstetter, considered these rocks in the North Island as oligocene, or upper eocene.† In 1866, Dr. Hector seems to have altered his views as he then classed the rocks of Oamaru, Waireka, and Caversham, as upper pliocene (?); those of the Waitaki and Lake Wakatipu, as older pliocene; and those of Green Island only as miocene.‡ In 1870, however, in his catalogue of the Colonial Museum, he considered the Oamaru rocks to be older tertiary; and those of Waitaki, Caversham, Tokomairiro, and Wakatipu, as middle tertiary and in 1871, he placed the Oamaru beds as the upper member of his "cretaceo tertiary" formation.§ In 1872, in my "Synopsis of the younger formations of New Zealand," I considered the Waitaki and Wakatipu rocks to be lower oligocene, and those of Oamaru, Caversham, Winton, &c., to be upper eocene; and in my catalogue of the tertiary mollusca, in the Colonial Museum (1873), I abandoned the term oligocene, in deference to the wishes of Dr. Hector, and called them all upper eocene. Whether they ought to be called upper eocene or lower miocene is doubtful. I think the latter, because among the fossils are teeth of *Carcharodon megalodon*; a shark characteristic of the miocene rocks of Europe, and the species of shark are generally widely spread. *Dentalium giganteum* and *Cucullæa alta* ‖ are also found in rocks of supposed miocene age in Chile. On the other hand the species of *Aturia*¶ closely resembles *A. zic-zac* from the eocene rocks of Europe, but *A. australis* occurs in beds at Schnapper Point, in Victoria, which Professor McCoy considers to be oligocene or lower miocene, and which are probably the equivalents of our Oamaru formation.

Contemporaneous Eruptive Rocks.—No eruptive rocks are found associated with the older or Ototara group of strata, although it is possible that the earlier eruptions in the Port Chalmers district may have been contemporaneous with it. But at Oamaru Heads we have clear evidence that during the deposition of the upper or Trelissic group of beds volcanic action was going on.

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* Quarterly Journal Geological Society, 1865, p. 128.

† Reise der Novara, Geologischer Theil I., Band II., Abtheilung. Wien, 1865.

‡ New Zealand Exhibition Jurors Reports and Awards, 1866. p. 263.

§ Transaction, New Zealand Instiuute, IV., p. 345.

‖ Approaches *C. auriculifera* Lam., from the Mauritius, but distinct.

¶ Probably the same as *A. Australis* McCoy (Ann. Nat. Hist. 3rd series, 20 p. 192), which does not appear to have been described.

Oamaru.—We see here an anticlinal curve formed by basalts, and basaltic tuffs and breccias (fig. 7), interstratified with sand-

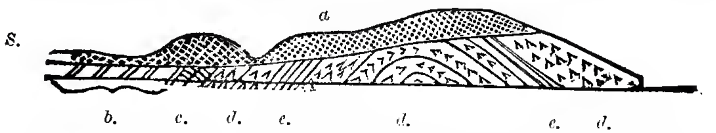

Fig. 7.—Oamaru Cape: *a*, Pleistocene silt; *b*, Pareora formation; *c*, limestone; *d*, volcanic rocks; *e*, soft sandstone (Oamaru formation).

stone (*e.*) and covered by limestone (*c.*), all belonging to the Oamaru formation. These volcanic ash beds often contain fragments of limestone, which have been generally altered by heat into a very fine grained lithographic limestone, but occasionally the fossils are still visible in them, shewing that they also belong to the Oamaru formation. These beds also often contain fragments of trachylite, or vitreous basalt, and they are cemented together by a calcareous cement, sometimes containing fossils, which shews that limestone was being formed in the sea during the time that submarine volcanic action was going on. These ash beds, therefore, must have been originally deposited in a horizontal position. At the southern end of the cape, beds belonging to the Pareora formatio (*b.*) overlie those belonging to the Oamaru formation quite conformably, and it is, therefore, evident that the folding of the rocks which caused the anticlinal curve at Oamaru Cape, took place long after volcanic energy had ceased to exist in the neighbourhood.

Dunedin.—The neighbourhood of Dunedin, as far north as Blueskin Bay, is the most interesting volcanic district in Otago. The main mass of the hills between Port Chalmers and Blueskin is composed of trachyte tuff and breccia, intersected with dykes of basalt and phonolite. The peninsula on the eastern side of the harbour is very complicated in structure, basalts and trachytes being mixed in the most confusing manner; while apparently underlying both there is at Portobello an extensive development of a rather coarse textured propylite, composed of greyish green felspar with crystals of hornblende, and other allied rocks. The trachytes and basalts in the southern part of the peninsula overlie sandstones and limestones of tertiary age, as has been already mentioned. The relation of the propylites to the sedimentary rocks is not very clear, but I am disposed to think that they underlie them. This, however, would not necessarily imply that the propylites are older than the sedimentary rocks, for the coarse crystalline texture of the former shews that they are true eruptive rocks. This, however, is a question that must be left for the present unsettled.

All round this centre of more or less trachytic rocks, from Tairoa Head, Cape Saunders, Tomahawk Bay to Forbury, and from there, through Dunedin to Flagstaff and Swampy Hill, and on to Blueskin Bay and Purehurehu, runs a band of basalts.

And other outlying patches of basalt are found at Stoney Hill, Saddle Hill, East Taieri, and North Taieri. The southern limits of the trachyte appears to be Anderson's Bay on the east, and Pine Hill on the west, both of which are trachytic. Bell Hill in Dunedin is composed of phonolite, a rock intermediate between trachyte and basalt. Interstratified among the volcanic rocks are small seams of coal, but it is highly improbable that any of them can have sufficient extent or thickness to enable them to be profitably worked.

The general structure of this volcanic district has a considerable analogy to that of the Thames goldfields, but it is on a much smaller scale. The propylites of Portobello resemble in mineral character those of the Thames, but they are more coarsely crystalline than the larger portion of the rocks at the Thames. At the latter place also, the outskirting basalts, although not altogether absent, are much more feebly developed than in the Dunedin district, where the propylites take a quite subordinate place. These differences, in my opinion, show that the conditions have not been so favourable for the production of metalliferous veins in the Portobello district as at the Thames; still, the resemblance is sufficiently close to warrant the hope that auriferous veins may be found here also.

It is probable that these propylites underlie, at a considerable depth, the basalts of Dunedin, for fragments of a very similar rock are occasionally found embedded in the basaltic lava streams, and appear to have been brought up by them from below. The Dunedin basalts also contain several zeolitic minerals as well as aragonite and quartz.

North of Blueskin.—Basalts, probably belonging to this formation, are found at Waikouaiti, and capping several hills in the neighbourhood of Palmerston, such as Puketapu, Mount Royal, Janet Peak, Smylers Peak, &c. On the north side of the Horse Range, they occur at South Peak, lying on rocks belonging to the Waipara formation; and Mount Charles, at Otepopo, is almost entirely composed of a coarse grained dolerite.

At the Maruawhenua there are two patches, and several more in the upper Shag Valley, where they rest either on rocks of the Oamaru formation (Fig. 8. *g.*) or on the schists.

On the eastern side of the Maniototo Plain they are extensively developed, from the Hound Burn to Taieri Lake, and also at Hamilton, and between the Sow Burn and Pig Burn; in all these cases lying apparently directly on the schists Lower down the Taieri they are found at the Mare Burn and Scrub Burn, near Hyde (see Sec. III.), also lying on schist.

South of Dunedin.—They are found at Otokaia, and on both sides as well as at the head of Waihola Lake. A basalt dyke also crosses the northern base of Mount Misery (see Sec. VII). I know of no other basalts in the Province except at Mount

Pleasant, on the east of the Longwood Range, and another patch of dolerites and basalt at the north-east corner of the Longwoods. Basalt boulders, however, occur on the hills at Bendigo, near the junction of the Lindis with the Clutha; and basalt scoria has been picked up on the shores of Lake Te Anau, so that probably there are other localities where basalt rocks occur, "in situ" in the centre of the Province, which have not yet been found.

Nomenclature.—The name of Ototara limestone was applied by the Hon. W. Mantell in 1850 to the Oamaru building stone, and this name I adopted in 1872 for the whole formation, but in 1873 I divided the formation into two groups, naming them Ototara and Trelissic respectively, and calling the whole by the name of the Oamaru formation. It includes both the Aotea and Papakura series of my former papers on the geology of some parts of the North Island.

Pareora Formation.

Distribution.—This formation is found in the Oamaru district, skirting the seaward side of the low hills between Oamaru and the Waitaki plains, and south of Oamaru to beyond the mouth of the Awamoa. Judging also from a few fossils that I received from the Waitaki, near Otakaik, I suspect that an outlier exists there also, but I have not seen it. South of the Kakanui River it extends to the Otepopo River, and runs north between the Oamaru and Kakanui formations to the Waireka. South of the Otepopo River it extends through Hampden to Moeraki and Kartiki Beach. Up the Shag River it is found as far as Coal Creek, and it forms the whole of the coast from the mouth of the Shag River to Waikouaiti Harbour. In the southern part of the Province it is found on the sea coast between the Tokomairiro and Clutha Rivers, at Wangaloa or Measly Beach (Sec VII., d.) It also occurs in the bed of the Pomahaka below Tapanui, and rises to an elevation of 1180 feet in the Conical Hills. Near Riverton it is again found in the bed of the Pourakino Stream, which flows out of the Longwood Range. In the interior it is extensively developed on the east side of Lake Te Anau from the Eglinton to the Whitestone River, and Mount Prospect; but the boundary between this and the younger lacrustine beds are here not easy to make out without a closer examination than I had time to give to the district. There are also in the museum two fragments of rock enclosing marine fossils belonging to this formation, which are labelled as coming from the Carrick Ranges, but I do not know whether they were obtained in situ or only from boulders.

Rocks.—This formation generally consists of blue sandy clay, often with calcareous concretions, which between Moeraki and Hampden assume the form of true septaria, and have sometimes on their exterior surface fine examples of that peculiar form of crystallation known as "cone-in-cone structure." Between the Shag

River and Waikouaiti bands of hard calcareous sandstone are interstratified with it, and at Wangaloa the rocks consists almost entirely of sandstones. In the Pomahaka district the upper beds, which form the Conical Hills, are composed of a white sharp quartz grit containing beautiful impressions of leaves of dicotyledonous plants, which have not yet been described. Inferior brown coal is also found in the Shag Valley and Pomahaka.

Position of Strata.—This formation is usually nearly horizontal in Otago, but on the south side of Oamaru Cape a blue clay belonging to it is seen lying on the Oamaru beds, and dipping conformably with them at an angle of 37° S.W. (Fig. 7, *b*.), but they soon get horizontal.

Relation to Underlying Formation.—As the Ahuriri formation, which should come in between this and the Oamaru formation, is absent in the Province,* the just mentioned conformity can be only apparent, and this is plainly seen in the Kakanui district, and also at the Shag River, where it warps round the bases of Mount Royal, Puketapu, and Janet Peak, all of which are composed of rocks belonging to the Oamaru formation, the beds of both series being horizontal. Up the valley the same thing can be observed, *i.e*., the newer beds lying at lower levels than the older ones, while both are horizontal. A good example can be seen at Coal Creek, across which the annexed section (Fig. 8) shows the Oamaru series,

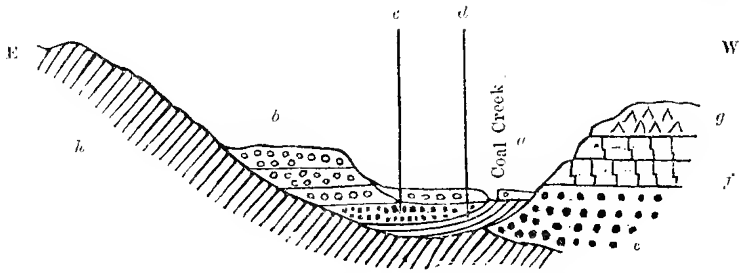

Fig. 8.—Coal Creek, Shag Valley: *a*, River alluvium; *b*, older river gravels; *c*, sand with concretions; *d*, shale with lignite (Pareora formation); *e*, green sandstone; *f*, limestone (Oamaru formation); *g*, basalt; *h*, schist (Kakanui formation).

(*e*, *f*, *g*), which once filled the Shag Valley, denuded away by Coal Creek, and beds of the Pareora formation (*c*,*d*,) deposited in the hollow.

Thickness.—I have not been able to estimate the thickness of these rocks.

Fossils.—I am acquainted with 154 species of mollusca from this formation, 58 of which, or 37½ per cent., I consider to be identical with still living forms. The following list gives the names

*Vide ante p. 25.

of all the fossils belonging to this formation that have been found in Otago. The species of *Mitra*, *Fasciolaria*, and *Conus* are all small, while the scarcity of the large species of *Cucullæa*, so common in Otago during the Oamaru formation, and common in the northern parts of New Zealand during the Pareora formation, is remarkable, and points probably to a decrease in the temperature of the sea.

	Awamoa.	Waitaki.	Hampden.	Shag Valley.	Mount Royal.	Wangaloa.	Pomahaka.	Pourakino.	Lake te Anau.
MOLLUSCA—									
Dentalium mantelli, *Zittel*	*	*	*						
„ irregularis, *Hutton* ...	*		*					*	
„ conicum, *Hutton* ...	*								
„ lævis, *Hutton*						*			
Fusus australis, *Quoy*			*						
„ mandarinus, *Duclos*	*								
„ plicatilis, *Hutton*							*		
„ nodosus, *Quoy*			*						
„ „ var γ			*						
Pleurotoma buchanani, *Hutton* ...	*		*						
„ traill, *Hutton*	*	*							
„ awamoaensis, *Hutton* ...	*	*							
„ pagoda, *Hutton* ...	*	*							
Bela striata, *Hutton*	*								
Triton spengleri, *Chemn*	*	*							
„ minimus, *Hutton*	*								
Cominella nassoides, *Reeve* ...	*								
„ funereum, *Gould* ...	*								
„ robinsoni, *Zittel*	*								
„ *sp.*			*					*	
Ancillaria hebera, *Hutton*	*		?					*	
„ pomahaka, *Hutton* ...							*		
Voluta pacifica, *Lam* var γ ...			*						
„ subplicata, *Hutton*	*								
Mitra apicalis, *Hutton*	*	*			?				
Amycla, *sp.*	*		*		*				
Marginella albescens, *Hutton* ...	*	*			*				
Fasciolaria, *sp.*					*				
Natica zealandica, *Quoy*			*			*			
„ ovata, *Hutton*	*							*	
Neritella nitida, *Hutton*							?		
Lunatia, *sp.*	*	*	*		*				
Sigaretus subglobosus, *Sow.* ...	*								
Conus ornatus, *Hutton*	*	*						*	
„ traill, *Hutton*	*								
Struthiolaria nodulosa, *Lam.* ...			*						
„ scutulata, *Desh* ...	*								

	Awamoa.	Waitaki.	Hampden.	Shag Valley.	Mount Royal.	Wangaloa.	Pomahaka.	Pourakino.	Lake Te Anau.
MOLLUSCA—									
Struthiolaria cincta, *Hutton*, var γ ...	*							*	
" tuberculata, *Hutton* ...									*
" *sp.*	*							*	
Cerithium rugatum, *Hutton* ...							*		
" cancellatum, *Hutton* ...			*						
Rissoa vana, *Hutton*	*								
Turritella rosea, *Quoy*			*			*			
" vittata, *Hutton*									
" gigantea, *Hutton* ...								*	
" tricincta, *Hutton*, var β ...	*	*	*						
" bicincta, *Hutton* ...				*		—			
" *sp.*	*		*					*	
" ornata, *Hutton*							*		
Phorus conchyliophorus, *Born* ...	*								
Calyptræa maculata, *Quoy* ...	*								
Crypta incurva, *Zittel*	*								
" profunda, *Hutton*	*								
" contorta, *Quoy*			*						
" ungiformis, *Lam.*	*								
Trochus stoliczkai, *Zittel*	*								
Emarginula striatula, *Quoy* ...	*								
Cylichna striata, *Hutton*	*							?	
Saxicava arctica, *L.*	*								
Corbula dubia, *Hutton*	*								
Zenatia acinaces, *Quoy*	*								
Psammobia stangeri, *Gray*... ...	*								
" affinis, *Reeve*								*	
Tellina alba, *Quoy*	*								
Chione stuchburyi, *Gray*			*						
" vellicata, *Hutton*	*					?	*		
" accuminata, *Hutton* ...							*		
" mesodesma, *Quoy*	*								
Callista disrupta, *Desh*			*					*	
Dosinea subrosea, *Gray*	*								
" grayi, *Zittel*				*					
Tapes intermedia, *Quoy*	*								
Venericardia intermedia, *Hutton* ...	*	*							
Lucina divaricata L	*								
Mysia zealandica, *Gray*	*								
Crassatella trailli, *Hutton*	*								
Trigonia pectinata (?), *Lam*... ...				*					
" semiundulata, *M'Coy* ...	*								
Cucullæa, *sp.*						*			*
Pectunculus laticostatus, *Quoy* ...						*			
" globosus, *Hutton* ...						*			

	Awamoa.	Waitaki.	Hampden.	Shag Valley.	Mount Royal.	Wangaloa.	Pomahaka.	Pourakino.	Lake Te Anau.
MOLLUSCA—									
Limopsis insolita, *Sow*			*						
,, zealandica, *Hutton* ...	*	*							
Nucula nitidula, *Adams*								*	
Solenella australis, *Zittel*	*	*	*						
Hinnites trailli, *Hutton*	*								
Pecten hochstetteri, *Zittel*	*								
Lima colorata, *Hutton*	*								
BRACHIOPODA—									
Rhynchonella nigricans, *Sow* ...	*								
POLYZOA—									
Pustulipora zealandica, *Mantell* ...			*						
ECHINODERMATA—									
Arachnoides placenta, *L.*	*								
,, conica, *Hutton* ...	*								
Schizaster rotundatus, *Zittel* ...	*								
ACTINOZOA—									
Turbinolia, *sp.*	*								
DIATOMACEÆ—									
Coscinodiscus, *sp.*			*						
Actinoclyclus, *sp.*			*						

In addition to the above, beautiful casts in sandstone of dicotyledonous leaves are found at the Conical Hills near Tapanui.

Age.—The Moeraki, or Hampden clay was considered by Dr. Mantell and Professor Morris in 1850 to be pleistocene. In 1866 Dr. Hector called the Pomahaka series miocene, and the Moeraki clay eocene. In 1870, Mr. C. Traill stated his conviction that the Awamoa beds were not younger than miocene. In 1872, I referred the Awamoa beds to the upper miocene, and those at Te Anau Lake to the upper oligocene; and in 1873, I referred the rocks at Awamoa, Hampden, Pomahaka, and Waitaki to the upper miocene, and the Te Anau beds doubtfully to the lower miocene. I now consider them all to be the upper miocene.

Contemporaneous Eruptive Rocks.—The basaltic rocks at Moeraki are clearly seen to overlie the blue clay of Hampden, and must therefore be younger than it. Consequently, there have been two distinct periods of volcanic activity in tertiary times

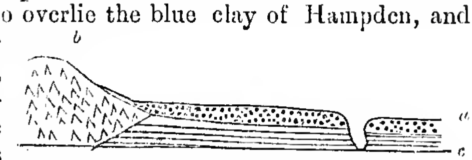

Fig. 9.—Moeraki roads; *a*, pleistocene silt; *b*, basalt; *c*, blue clay (Pareora formation).

in Otago; and it is quite possible that some of the basalts that I have enumerated under the Oamaru formation may properly belong here, but the proof of their age in most cases will be difficult.

Nomenclature.—The name of Pareora series was first applied by Dr. von Haast to some rocks in the south of Canterbury. I have not been able to find where this name was first published, and I have never examined the rocks myself, but took the name from Dr. Hector's catalogue of the Colonial Museum*

Ancient Glacier Deposits.

I have elsewhere† given my reasons for supposing that the greatest extension of our ancient glaciers took place during the interval between the Pareora and Wanganui formations, and in the next two sections I shall bring forward the additional evidence bearing on the question that I have collected during my survey of Otago. Of course as glaciers still exist in our mountains, our glacier deposits must range in age from the most ancient period of their greatest extension up to the present time, and in this place I only propose to describe the more ancient deposits.

This, however, is easily done, for, with the exception of the Blue Spur already described, I as yet only know of two morainic deposits in the whole Province that I am inclined to refer to this period. The first of these is the immense accumulation of clay and angular blocks of schist of all sizes that is found on the eastern side of the Taieri Plain, extending from the Taieri River nearly to Otokaia, a distance of about three miles. This deposit is a confused mass of quite angular fragments of schist, some of them of large size and composed of mica schist with quartz laminæ, which must have come either from the neighbourhood of Outram, or down the Waipori River. They could not have come from Brighton, on the sea coast, as many of the blocks are considerably above the highest level of the mica schists there, and there is no conceivable agency by which they could have been brought from there. Consequently, although I could find no trace of striæ upon them, I have very little doubt but that they were placed in their present position by a glacier descending from the Lower Taieri and the Waipori River.

Internally this deposit shows no signs of stratification, and is quite morainic in character, but externally it forms low rounded hills between 400 and 500 feet high that cannot be distinguished in outline from ordinary clay hills. The deposit is situated nearly opposite the place where the Waipori debouches, through a gorge, on the Taieri Plain, and it extends over to the sea coast; but on the seaward side it is covered by water-worn gravels nearly to the top.

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* Page 186.

† Transactions New Zealand Institute, V. p. 384.

The second old morainic deposit is the high terrace-like hill between the Redbank Creek and Black Mount. This hill contains large angular blocks of gneiss, intermingled with water-worn pebbles, and as none of these angular blocks are found below Black Mount, I suppose that this hill represents the terminal moraine of the great Waiau glacier. But the hill has quite lost the shape of a moraine. The top is flat and level, the slopes and minor vallies are quite regular, and the angular blocks are mixed up with numerous rounded pebbles.

The former great extension of the New Zealand glaciers was first pointed out by Dr. von Haast, in 1862,* and he attributed it to the effect of the glacial epoch, when the land was considerably lower than at present. In November, 1863, Dr. Hector, in his narrative of his geological expedition to the west coast of Otago, said that he thought that an elevation of the land equal to 2000 feet, combined with the greater extent of high land then existing but since removed "by the eroding action of the descending ice," would be almost sufficient to extend the glaciers to their ancient limits.†

In 1864 Dr. von Haast published his report on the formation of the Canterbury plains, in which he abandoned his former theory, and adopted that of Dr. Hector; but he laid the chief stress on the supposition that when the land emerged from the sea "the physical feature was a high mountain chain, plateau like, but with depressions existing before the tertiary submergence, but now partly obliterated, running generally either on the junction of two formations, on the lines of faults, or on the breaks of bold anticlinal curves."‡

In 1870, Mr. L. O. Beal considered that nearly the whole of Otago had been covered by an ice sheet, and attributed it to the cold of the glacial epoch.|| In 1872 I gave some reasons for thinking that the former extension of our glaciers was entirely due to greater elevation.§ In 1873 no less than three papers were read before different scientific societies in New Zealand on this subject, two of which, by Mr. A. D. Dobson,¶ and Mr. W. T. L. Travers,$ advocated the theory of the former elevation of the land being the

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* Notes on the Geology of the Province of Canterbury. Canterbury Provincial Government *Gazette*, 24th October, 1862.

† l. c. page 462.

‡ On this point see also Dr. Haast's "note on the climate of the pleistocene epoch of New Zealand. Quarterly Journal Geological Society, 1865, p. 135.

|| On the alluvial deposits of the Otago Gold Fields. Transactions New Zealand Institute, III. p. 270.

§ *Ibid* V. p. 385.

¶ Notes on the glacial period. Transactions New Zealand Institute, VI. p. 294.

$ On the extinct glaciers of the Middle Island. ib. p. 297.

cause; and the other, by Mr. J. T. Thomson, advocated the theory* that Otago was formerly covered by ice that descended into the sea, which was caused by a much colder temperature than now exists in New Zealand.

In 1874, Mr. W. T. L. Travers, in another paper on the subject† brought forward conclusive proof that New Zealand had never been covered by an ice sheet, as supposed by Messrs. Beal and Thomson, and in May, 1875, I read a paper to the Otago Institute in which I shewed by the distribution of the pleistocene and pliocene fossils that the climate of New Zealand had never been sufficiently reduced to account for the former extension of our glaciers; and that probably it was not in either pliocene or pleistocene times colder than it is now.

Wanganui Formation.

No marine beds of this age are found in Otago, but probably some of the lacrustine series in the interior belong to this period. There are, however, considerable difficulties in classifying all our rocks and alluvial deposits that are of post-miocene age, as they form two connected series very complicated in their relations to one another, and it will require an immense amount of close observation, before each deposit can be put into its proper place.

For the present, I think it best to consider this formation in Otago to be confined to the old lake basins in the interior, forming the Maniototo Plains, Idaburn Valley, Manuherikia Valley, the low land lying between Cromwell and the Carrick Mountains, portions of the Ohau plain, Cardrona Valley, the basin at Gipps-town, the low land between Lake Hayes and Arrowtown, the Waipori basin, the margins of the Taieri Plain and Waihola Lake, the Tokomairiro Plains, and the low hills between them and Kaitangata Lake; and a considecable, but undefined, area in the Mararoa and the left bank of the Waiau, as far as Black Mount.

These deposits present considerable similarity in the different areas. The lowest bed in the interior basins appears, whenever it has been penetrated, to be fine compact clay; while round the margins of the basins the beds are cements and gravels, soft sandstone and sands, and clays and shales often associated with seams of lignite; the beds always dipping from the hills towards the interior of the basin.

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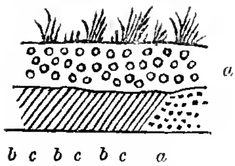
* On the glacial action and terrace formation of South New Zealand ib. p. 309.

†Trans. N. Z. Institute, VII. p. 409.



At Hamilton, on the south-east side of the Maniototo plain, fine grey and purple clays, lying on soft sandstone, are seen dipping 62° N., (Fig 10,) the whole being covered, unconformably, by pleistocene auriferous gravels.

Fig. 10.—Lacrustine deposits, Hamilton.
a. pleistocene gravels
b. grey clay
c. purple clay } Wanganui formation.
d. soft sandstone

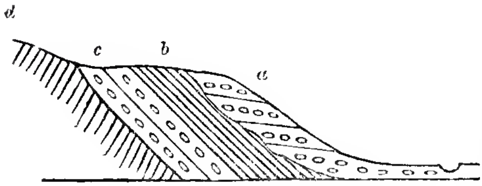


Fig. 11.—Lacrustine deposits, St. Bathans.
a. Pleistocene gravels
b. Shales with lignite } Wanganui formation.
c. Gravels
d. Schist (Kakanui formation).

At St. Bathans, near the head of the Manuherikia Valley, quartz gravels with shales and lignite, dip at varying angles, sometimes reaching 35° S.W. These rest on decomposed schist, dipping 45° N.E., and are covered unconformably, by pleistocene quartz gravels, dipping 20° S.W., (Fig. 11). In this case, both the pleistocene gravels and the older ones belonging to the Wanganui formation, contain gold.

In the bed of the Kawarau at Cromwell, sands and shales with lignite dip to the N.W. (fig. 12), while further to the south, in the

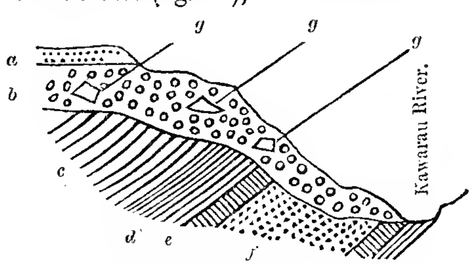


Fig. 12. Lacrustine deposits, Cromwell:—*a.* Sand; *b.* Gravel (Pleistocene). *c.* Shale; *d.* Carbonaceous sand; *e.* Lignite; *f.* Soft sandstone (Wanganui formation). *g.* Angular blocks of schist in gravel.

Bannockburn, soft sandstone and shales, with lignite, dip gently to the east, away from an isolated patch of schists, which stands out in the middle of the basin, and through which the Kawarau runs. On the north-western side of this hill, where the road goes after crossing the bridge, shales with leaves, probably belonging to this formation, dip 35° N.N.W.

Age.—Dr. Hector, who is the only geologist who has previously

written about these beds, refers them to the miocene period, considering them therefore to be anterior in date to the glacier period; but if my views are correct as to the glacier origin of the lakes, and also as to the date of the great glacier period, they must be of newer pliocene age. Dr. Hector also, in his section through Otago, published in the Quarterly Journal of the Geological Society, 1864, shews basalts breaking through and overlying lacrustine formations at Tuapeka and the Upper Taieri (Maniototo) plains; and in the section through the Manuherikia Valley that he sent to Professor Owen, which was published in the Trans. Zool. Society, V, he shews a "felspathic dyke" cutting through "older river gravels," or "older gold drift," of which the upper beds are "cemented with quartz." If these should be correct, they would considerably alter my views as to the age of the lacrustine beds, for we have no evidence of pleistocene volcanoes in Otago. I do not know the eruptive rocks mentioned by Dr. Hector at Tuapeka and the Manuherikia, but in the Maniototo Plains the lacrustine beds appear to me always to overlie the basalts.

The reasons that have induced me to refer these lacrustine deposits to the Wanganui formation will be given in the next section (*Glacier period*).

Fossils.—The only fossil as yet described from these beds is *Unio aucklandica* (?) from Clyde, but impressions of the same shell have been found in the Maniototo Plains and Millar's Flat. Leaves also occur at Cromwell, and a deposit of diatomaceous earth occurs in Strath Taieri. This deposit is chiefly made up of three or four minute species of *Cymbella* or *Cocconema*, and although I have not been able to determine any of them, I have no doubt but that they are freshwater species.

In the Cardrona Valley, the lignite beds, according to Mr. Wright, are perpendicular, and interstratified with yellow clay and green sandstone. Where the Cardrona joins the Clutha, high cliffs are exposed of yellow clay capped with silt and rolled stones. The top of these cliffs appears to me to be higher than the moraine at the south end of Wanaka Lake. (Fig. 14, b, c.)

In the Upper Waiau Valley, the rocks in Redbank Creek are gravels and sands with semicarbonised wood. These gravels are irregularly stratified like river gravels, but they are highly inclined, and, indeed, in one place nearly vertical. The pebbles consist of sandstone, jasperoid slate, quartz, and conglomerate; I saw none of eruptive rocks nor of gneiss. They are smaller than the stones now brought down by the creek, which would shew that the velocity of the creek was less, and that it probably fell into still water. These gravel beds are overlaid unconformably by younger gravels, the stones in which, like the creek bed at the present day, are composed chiefly of diorite, gneiss, and a conglomerate formed of small pebbles of jasperoid slate.

Pleistocene Deposits.

Newer Glacier Deposits, &c.

West Coast Sounds.—Up the Cleddau River Dr. Hector describes several moraines, and no doubt they exist in all the valleys running into the mountains, as they also do on the eastern side of the range. Dr. Hector also says that in the Waipero Cove, Crooked Arm, he made a careful survey "in order to obtain its exact form both above and below water, in order to test the theory of the glacier formation of these valleys. The average depth of water is 90 to 100 fathoms, to which depth the rocky sides of the valley descend at an angle of 35°, where there is a level mud bottom from side to side, which slopes gradually towards the main body of the Sound. The bank which bars across the valley, and forms the head of the bay, is a true moraine, its upper part consisting of angular blocks of rock of every variety found in the mountain, but in front this moraine is marked by a bank which has been formed of the finer materials brought down by the streams, and shot into deep water." * I may here remark that all the Sounds are much shallower at their mouths than inside—(see ante p. 5), but we cannot infer from this that that they all have submarine moraines across their mouths, for the shallowness may possibly be caused by ancient bars formed when the land was at a higher level. The islands in the Sounds are not "moutonnées," and although some of the smaller ones are rounded, they show no sign of a lee and strike side. The precipices on either side of the Sounds are also in general quite rough, and I only noticed two localities (both previously observed by Dr. Hector), where there was any appearance of polishing. One was in Milford Sound, on the south side of the entrance to the Narrows, where the rocks have decidedly the appearance of having been polished by ice, but I could not examine them closely. The other locality is near Deas Cove, in Thompson's Sound, but here the evidence is much more doubtful, although I am of opinion that it shows ice action. I saw no grooves nor striæ anywhere, but Dr. Hector says that in Thompson's Sound "the rock is a granitic gneiss, the hard surface of which has faithfully preserved the grooves and polished surfaces caused by ancient glaciers."—(l. c. p 458); and of the Cleddau Valley, he says that "the rock at the sides. where it forms steeply inclined slopes, is grooved and scattered like those of the Sounds."—(l. c., p. 461). Also speaking of Milford Sound itself he says "the lateral valleys join the main one at various elevations, but are all sharply cut off by the precipitous wall of the Sound, the erosion of which was no doubt continued by a great central glacier long after the subordinate

* Geological Explorations of the West Coast, p. 459.

and tributary glaciers had ceased to exist. The precipices exhibit the marks of ice action with great distinctness, and descend quite abruptly to a depth of 800 to 1200 feet below the water level."—(l. c., p 460.) But the strongest evidence in favor of glaciers having once occupied the Sounds is found in the large granite boulders that occur along the shore at the entrance to Preservation Inlet, which must have been brought by ice for some distance down the Sound. Near the entrance all these boulders have been more or less rounded by the action of the sea, but higher up, in Kisbee Bay, which is situated in slates, there are two large angular granite erratics, the larger of which is 15 or 20 feet high.

Waiau Valley.—The low land on the eastern sides of the Te Anau and Manipori Lakes, and across the Mararoa River, as far as the base of the Takitimus, is strewed with fragments of gneiss, greenstone, and other eruptive rocks, which must have come from the western side of the lakes, and have thus crossed a deep valley. All the smaller pebbles are rounded, but the larger blocks are angular. I saw no moraines either at Manipori or Te Anau Lake, except perhaps some low irregular hills covered with bush at the bend of the Waiau River into the Manipori Lake. These angular blocks extend down the Waiau to the hill between Red Bank Creek and Black Mount, but I saw none further down. I therefore suppose that this hill is the terminal moraine of the ancient Waiau glacier.

Wakatipu Valley.—Besides the numerous terminal moraines in the vallies of the Rees, Dart, Route-burn, &c., and in most of the valleys between Lakes Ohau and Te Anau, lateral moraines are found on both sides of Lake Wakatipu. That on the eastern side contains many angular and rounded boulders of sandstone and greenstone tuff that must have come down either the Dart or the Greenstone, and must therefore have crossed the Lake. This lateral moraine forms the false bottom of the miners, and is covered by auriferous gravels containing boulders of schist only. At Kingston a large and well-marked moraine is seen crossing the valley, the blocks in it being schist, sandstone, and greenstone tuff. The valley between Kingston and the Mataura is also covered with angular stones, but I saw no evidence of the glacier having ever extended down below Athol. The most noticeable feature in connection with the Kingston moraine is that the southern or lower side of it is not abrupt, as is ordinarily the case, but slopes gently away to the Mataura, and, losing gradually its morainic character, it passes into the alluvium of the Mataura as if both were of the same age.

Clutha Valley.—Both Lake Wanaka and Lake Hawea are bounded at their southern ends by moraines; but both of these moraines, especially that of Wanaka, are much worn, and slope

gradually away into the alluvial plains. This latter feature is

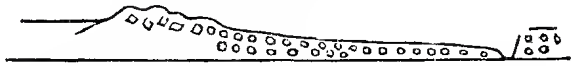


Fig. 13.—Terminal moraine of Lake Hawea.

not so much marksd in the Hawea moraine (fig. 13), as in that of Wanaka, (fig. 14.) Indeed the latter is so much woru, and so

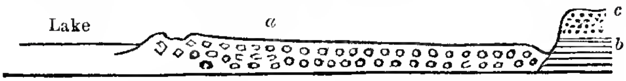


Fig. 14.—Terminal moraine of Lake Wanaka: *z*, gravel and silt; *b*, grey silt; *c*, yellow clay, (Wanganui formation.)

covered with silt at the surface, that if it were not for its crescent shape, the irregularity of its surface, and the occasional occurrence of large angular boulders, its presence would hardly be detected; for the alluvial deposits slope from the Cardrona quite to the top of the moraine. At the junctiou of the Lindis with the Clutha, a large moraine appears to have ouce existed; but it is now quite destroyed, aud marked ouly by the number of large angular blocks that lie on the surface, and are mixed up with the alluvial deposits. These angular blocks are found in the alluvium overlying the lignite formatiou as far down as Cromwell—(see fig. 12, *g*), and are very conspicuous at the entrance to the Kawarau Gorge ou the Cromwell side. Below Cromwell I have seen no glacier deposits, neither have I seen any in the valley of the Waitaki, nor in any other part of the Province except those described.

Dunedin.—It has been stated * that evidence of ice action in the form of striated boulders, rock groovings, and boulder clay, existed in the neighbourhood of Dunedin. I have several times carefully examined the evidence upon which these statements rested, once in company with J. T. Thomson, Esq., and Dr. Berggren, of the University of Lund, in Sweden, who is well acquainted with ice marks, and on auother occasiou with L. O. Beal, Esq., and Mr. Ulrich, who has a most extensive knowledge of rocks and miuerals. We found the supposed glacial striæ very numerous on rounded basalt blocks. But although remarkably like true ice scratches, they were found on close examination not to be parallel, and even occasioually slightly curved. They were also fouud to be chiefly on the edges of the blocks, and often went round a corner. These facts were decisive against the scratches being due to ice action, and we came to the conclusion that they were caused by decomposition, bringing into view a previously hidden internal structure

* Trans. N. Z. Institute III., p. 276, and VI., p. 312-313.

of the rock. This opinion was subsequently confirmed by finding similar striæ on hard cores of basalt in a decomposing lava stream, where of course they could never have been exposed to any abrading action. It is these decomposing basalts, out of which the harder undecomposed cores project and look like rounded boulders irregularly scattered through a clay, that have, in the neighbourhood of Dunedin, been mistaken for a glacial boulder clay, or till. The grooved rocks in the valley of the Kaikorai were found to be caused by water running over calcareous sandstone, and dissolving narrow gutters out of it.

Shore Deposits—At Oamaru a horizontal thick bed of fine grey silt, interstratified in its lower portions with several beds of well rounded gravel, rests unconformably on the volcanic and sedimentary tertiary rocks (Fig. 7, *a*). This deposit, which descends nearly to the sea level at Oamaru jetty, wraps over the highest points (470 feet) of the volcanic rocks forming Oamaru Cape, and descends again on the other side nearly to the sea level. The lowest gravel beds on both sides of the Cape are full of marine shells, and out of them I obtained the following :—*Ranella vexillum, Euthria lineata, Voluta pacifica* var γ, *Cominella virgata, Calyptræa maculata, Turbo smaragdus, Diloma æthiops, Diloma nigerrima, Polydonta tiarata, Patella margaritaria, Mactra æquilatera, Mactra* sp. nov., *Mesodesma novæ zealandiæ, Mesodesma subtriangulata, Chione costata, Chione mesodesma, Chione gibbosa, Dosinea anus, Tapes* sp. nov., *Mytilus latus, Mytilus dunkeri*, and *Ostrea purpurea.*

Of these, 22 species all but two are still living, but *Cominella virgata* is not known to live as far south as Oamaru at the present day. Many of the bivalve shells appear to be thicker than they are now, but *Diloma æthiops, Diloma nigerrima, Polydonta tiarata,* and *Patella margaritaria* still partly retain their color.

In the same bed Mr. Forrester has obtained rolled specimens of *Natica solida* and a *Cucullæa*, but these are very much waterworn, and have evidently been derived from an older formation. This bed is not more than 10 or 12 feet above the sea, but marine shells occur in other gravel beds filling old caves, to a height of 60 feet on the north side of Oamaru Cape.

In the silt overlying the gravels many bones of the moa are found at all levels from a little above the fossiliferous gravel bed to quite the upper portions, and I also obtained some fragments from the same deposit in the terrace above Oamaru.

In Fig. 15 I have given a sketch of a section exposed in a

gully on the north side of Oamaru Cape as it appeared in November, 1873, with the broken pelvis and femur of a moa (Dinornis) sticking out of it (fig. 15, *e*). The femur and pelvis were found in their proper positions. There is also in the Museum the skull of a sea elephant (*Morunga elephantina*) which was obtained from this silt several miles inland from Oamrru, but I do not know the exact locality.

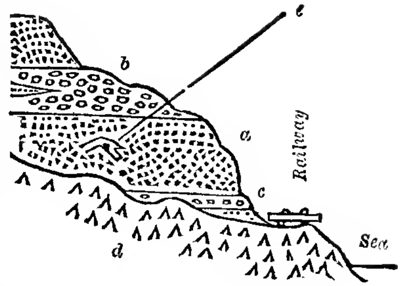


Fig. 15. Silt bed at Oamaru—*a*, silt, *b*, gravel; *c*, gravel with marine shells, pleistocene; *d*, basalt (Oamaru formation); *e*, moa bones in silt.

This silt extends inland for a considerable distance, and stretches northwards as far as the shingle alluvium of the Waitaki. It appears to present a considerable analogy to the Pampean formation of South America.* Southwards it is extensively but irregularly developed. At Hampden it is seen to rest on the blue clay of the Pareora formation (fig. 9 *a*).† At Waikouaiti and Blueskin it passes into a sandy clay; and at Dunedin, a clay, that I consider to be of the same age, covers a considerable area at Mornington at a height of 450 feet above the sea, where it rests upon volcanic rocks.

From the Otokaia southward to Tokomairiro, beds of fine gravel occur along the shore and extend inland, eovering up the old moraine deposit, previously mentioned,‡ to a height of at least 300 or 400 feet.

From Wangaloa to the Clutha beds of horizontally stratified sands and gravels are found along the top of the sea cliff (see. VII. a), and extend inland to a height of about 150 feet. I could find no fossils in these roeks, but they have every appearance of being very reeent.

The eountry also between Balclutha and Clinton is thiekly covered with silt, the older rocks only appearing occasionally, and generally in the valleys.

The Southland plains, extending from the Mataura to the Jacob's River, may also be considered a shore deposit. They are composed of beds of shingle, sand, and elay, with occasional seams of lignite in the lower portions. These beds rise gradually from the sea, and attain a height of about 650 feet in the Waimea plains.

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*Darwin's Geological Observations in South America, p. 99.

†It is the (1) diluvial clay of Mr. Mantell, Q.J.G.S., 1850 p. 324.

‡Ante, p. 62.

A similar set of beds are seen on the coast at Orepuke (fig. 26, *a*).

Older River deposits.—Many of the rivers in Otago have on one side or the other old beds filled up with gravel and silt, and separated from the present river bed by a ridge of solid rock. In the Shotover, for instance (Fig. 16), one of these old river beds is worked for gold on the right bank of the river, a gallery being driven along the old channel, the schist rock rising up on both sides. The present river bed is cut down considerably lower than the old one.

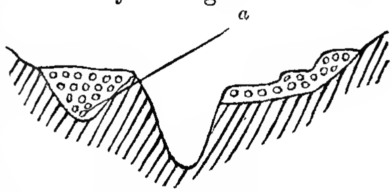


Fig. 16. Shotover River.—*a*, old river channel.

The same thing occurs in the Lammerlaw Creek, at Waipori, where Driver's and Bolton's claims are worked in an old channel of the river, which is completely covered up and hidden by gravel and silt, and divided from the present river by a ridge of rock. In this case also the river is now running at a lower level than the old one did. Another example of the same thing may be seen at Few's Creek, Lake Wakatipu; and no doubt many others of a similar nature exist.

In the Dunstan gorge the river is seen to have once run in a broad channel which has been filled up with gravel and silt, and a new and much narrower channel has been cut through the alluvial beds and deep into the solid rock below (fig. 17.) In these older silt beds moa bones are of not uncommon occurence (fig. 16, *a*).

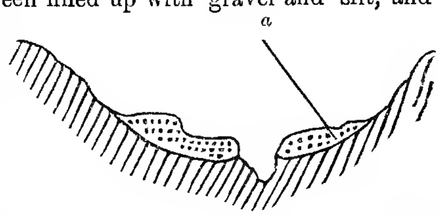
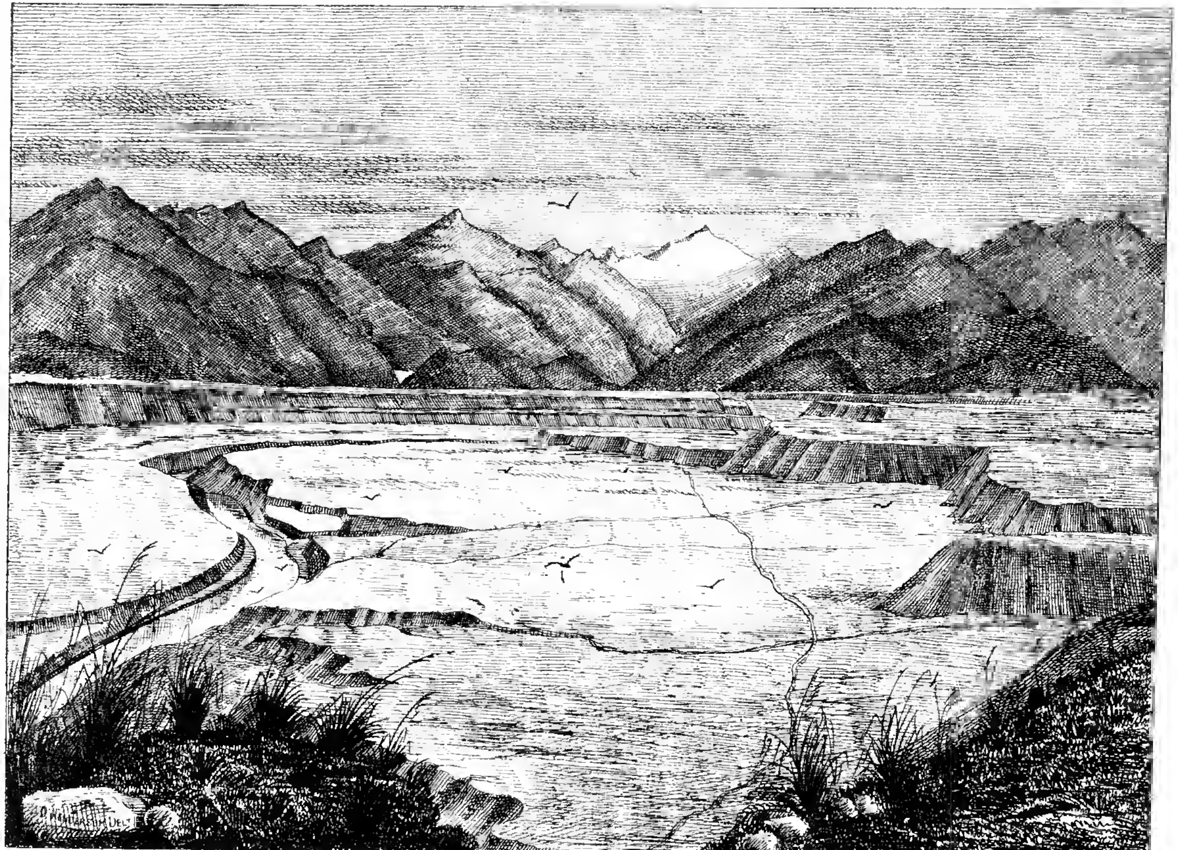


Fig. 17. Dunstan Gorge.—*a*, Position of Moa bones in silt,

Under this head we must also arrange the river terrace formation which is so largely developed in the interior of the Province. These terraces are found in the valleys of all the rivers, but are particularly well seen in the Upper Clutha (see plate I.) These older river alluvia, which cover the still older lake deposits,* are of course very variable in character, but a general rule in their composition appears to be that the upper beds are composed of finer materials than the lower, the whole being often capped by fine sand or silt (see fig. 12, *a*).

* See figs 10 and 11 (*a*), and fig. 12, *a* and *b*.



From a Sketch by J. Buchanan

RIVER TERRACES, UPPER CLUTHA.

Recent Deposits*

Under this head I arrange all the gravel and silt beds now being formed by the various rivers (fig. 8, *a*), or by other causes still, or quite lately, in operation; such as the sand dunes at the mouths of the rivers, the peat beds often, as at Hamilton, containing moa bones, the raised estuarine mud round the head of Dunedin Harbour, Inch-Clutha, &c., and also the Cave deposits in various parts of the Province. It is only in the uppermost parts of these deposits that we find any trace of the human race, and of terrestrial mammalia, which latter are, however, limited to the dog and rat. Associated with these, and evidently contemporaneous, we also find many remains of the moa, the species of which appear to be identical with those found in the pleistocene deposits. From the peat at Hamilton I obtained species of land and fresh water shells, which have been sent to Dr. Dohrn for determination, but I have not yet received any reply from him. The following species of extinct birds have been found in the recent deposits of Otago:—*Harpagornis moorei*, Haast; *Cnemiornis calcitrans*, Owen; *Dinornis didiformis*, Owen (?); *D. rheides*, Owen; *D. gravis*, Owen; *D. casuarinus*, Owen; *D. crassus*, Owen; *D. elephantopus*, Owen; *D. struthioides*, Owen; *D. ingens*, Owen; *D. robustus*, Owen; and *D. maximus*, Owen. In addition remains of the Tuatara Lizard (*Sphenodon punctatum*, Gray), which is now extinct in the Province, are also found, as well as of many smaller birds, which have not yet been examined.

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* These are not represented in the map.

SECTION V.

Historical Geology.

Having described all the facts known to me relating to the geology of the Province, it remains now to collate them, and try to deduce from them the causes to which they owe their origin, or in other words the geological history of the Province. I have kept this section distinct from the last because it stands on a differeut footing. The last section simply described my observations, which are open to all to examine and verify or correct as the case may be; while the present section is an attempt to theorise on those observations, and to build up from them a history of the geological changes that have taken place in this portion of the earth's surface. But as these observations are necessarily very incomplete, and indeed sometimes probably erroneous, it is evident that too much stress must not be laid on the accuracy of the conclusions drawn from them. Even if all the facts were as accurately known as possible, the interpretation of them would not be so easy as might be supposed, for sometimes the facts admit of more than one explanation. Nevertheless whatever may be the difficulties in the way, we must try our best to overcome them, for not only will a knowledge of the geological history of New Zealand be of the utmost importance to general theoretical geology, but it will also throw much light on the deposition of our auriferous alluvia, and it has therefore its immediate practical, as well as its future theoretical value. Consequently it is of no use saying that we ought to wait until our knowledge is more complete before attempting to theorise, for if we did so we might wait for ever, and still not be satisfied as to the fullness of our evidence; while if we carefully endeavour to make out from the observations before us the most probable history of the geological changes in Otago, we shall at any rate be in the best possible position that our present knowledge admits of for solving accurately the practical problems presented to us.

Eozoic and Palæozoic eras.—Our knowledge of the eozoic and palæozoic rocks of Otago is too limited to enable us to speculate much about them. It is, however, evident from the facts previously mentioned (page 40), that the metamorphism of the Manipori formation has no connection with the eruption of granite at Pre-

servation and Chalky Inlets, and that most probably the metamorphism of the Wanaka and Kakanui formations took place during or after the deposition of the rocks of the Kaikoura formation; and, as the Kaikoura formation is not more altered where it rests on the Manipori formation than it is at other places, it follows that the more intense metamorphism of the latter formation must have occurred at an earlier period than that of the Wanaka and Kakanui formations. This shows a considerable difference in age between the Manipori and Wanaka formations, which is further proved by the abundance of dykes in the former which do not appear to penetrate any higher.

The slight unconformity that exists between the Kakanui and Kaikoura formations, shows that, at an intermediate age (perhaps during the Devonian period), an extent of low flat land existed in Otago which underwent a slight denudation. This land, the earliest of which we have any evidence in New Zealand, sank during the deposition of the Kaikoura formation (perhaps the carboniferous period), and was afterwards elevated again into dry land in the Permian period.

This last elevation is proved by the unconformity that exists between the Maitai and Kaikoura formations, which, however, is not so great in Otago as it is further north. But even in the north there is perhaps no evidence that New Zealand, during the Permian period, was a mountainous region, for there are no signs of any great local denudations having taken place, such as would be produced by mountain streams, and it is more probable that New Zealand then formed a very subordinate part of a large continent, which, judging by the similarity of the shells and plants found in the following formations with those found in Australia, India, and Europe, probably stretched away far to the northward.

Mesozoic era.—At the commencement of the triassic period, this continent began in New Zealand to subside below the sea; but from the occurrence of plant remains throughout the Maitai formation, it is probable that this subsidence was not very great, and that the southern portion of the Permian continent was not yet quite submerged, when another slight elevation, accompanied by an outburst of volcanic action, took place, which caused the continental vegetation again to advance to the southern and western portion of New Zealand. This was followed by subsidence, during which the mixed estuarine and marine Putataka formation was deposited. The granite also, erupted into the palæozoic rocks during the deposition of the upper part of the Maitai formation, was exposed at the surface by denudation, and fragments of it were brought down by rivers running from west to east and were mixed with the gravel on the sea shore. At the close of this formation (that is to say towards perhaps the middle of the jurassic period), the whole of the country was again elevated, and the chain of the New Zealand Alps formed.

The proofs of this elevation are (1), That all the rocks of precretaceous age partake in the main foldings of the strata (see page 24); (2), The absence of all rocks belonging to the upper jurassic and lower cretaceous periods, and (3), The total unconformity between the Putataka and the Waipara formations, which is especially well seen in the Provinces of Canterbury and Marlborough, where rocks belonging to the Waipara formation are found filling up valleys of erosion in the Maitai and Putataka formations, proving conclusively that the country had previously undergone a considerable amount of subærial denudation. The foldings of all the rocks older than the Waipara formation, show that this upper secondary elevation was no local affair, but part of a large movement, which probably resulted in the upheaval of a continent. How far this antarctic continent extended we have as yet no means of knowing, but that it probably extended to South America is shown by all the formations later than this upheaval containing fossils related to, or identical with those of Patagonia and Chili. Since this upheaval the New Zealand Alps have never been submerged.

Subsequently (upper cretaceous period) this continent subsided, and at the close of the mesozoic era, the north part of this island was 6000 feet, and Otago was 3000 feet lower than at present. This is proved by the height to which the Waipara formation extends in Marlborough (Benmore) and Otago (Mount Hamilton) respectively. That the Alps were not entirely submerged, is shown by the Waipara formation, which was deposited during this depression, abutting against the older rocks, and occurring in such positions as to show that it could never have overspread the whole of the Alps. This, however, can be better proved in Canterbury and Marlborough than in Otago. It was at this time that the sea swarmed with huge saurians (plesiosaurus, &c.), and although none of their remains are as yet known to occur in Otago, they may still be found between Shag Point and the Otepopo River in the hills behind Hampden.

New Zealand was now reduced to a narrow chain of islands, and from that time to the present it has always remained isolated from any large continental area.

Cainozoic era.—At quite the commencement of the tertiary era, New Zealand was again upheaved. This upheaval was not so violent as the last, and probably therefore did not affect so large an area. Still in Otago, Marlborough, and Nelson, a certain amount of folding of the rocks took place, and the lately formed beds of the Waipara formation were caught up in them. In Canterbury, however, this was not the case, and the Waipara beds still continued in a horizontal position, although elevated above the sea*

*I mention these facts, although referring to districts outside of Otago, as we are by means of them enabled to roughly estimate the difference between this and the former elevation. They are all derived from personal observation of those districts.

The proofs of this upheaval are—(1) The complete uniformity between the Waipara and Oamaru formations as seen at Mount Hamilton (see p. 51) and Shag Valley (see p. 50) in Otago, and in the Weka pass, district in Canterbury.* (2) The absence of rocks of lower eocene age, the fossils from the Oamaru formation being quite distinct from those of the Waipara formation, and containing some 13 or 14 per cent. of still living forms; and (3) the great amount of subærial denudation that had taken place between the two periods, such as the hollowing out of the Shag Valley (see p. 50), and the denudation of the north side of Mount Hamilton and Centre Hill (see p. 51).

It was this lower eocene upheaval that gave the final form to the internal geological structure of the Alps, for all the rocks of a later date are, with local exceptions, more or less horizontal, and circle round the bases of the hills formed by the mesozoic and palæozoic rocks. Thus showing that since the deposition of the tertiary strata no great *internal* changes in the position of the rock masses have taken place, although vast *external* changes, caused by denudation, have torn the tertiary rocks into fragments.

But not only was the last touch given at this time to the geological structure of the Alps, but the chief valleys were also marked out at this period. For example, we find our oldest tertiary rocks occupying the valley of the Waitaki as far as Big Gully Creek, and the Maruwhenua to beyond the township. In the valley of the Shag they extend up nearly to its source, stretching indeed once beyond that into the Maniototo Plain as far as the Kyeburn. We find them again at Waihola gorge, and at Lake Wakatipu, and in some of the branches of the Shotover, shewing that these even had been hollowed out during the eocene period. In the valley of the Mataura they occur in the Waimea Plains, and they stretch up the valley of the Waiau as far as Manipori Lake and Centre Hill. These facts prove convincingly that the Alps had undergone enormous denudation before the close of the eocene period, and that most of the present valleys in them had been hollowed out to a considerable extent at that time. But they also prove that at the close of the eocene period Otago was again depressed to about 1500 or 2000 feet below its present level, and that the sea then entered the long winding valleys that had been previously formed, and penetrated as far as Te Anau and Wakatipu Lakes. It was at this period of greatest depression that volcanic action burst out with such energy in the neighbourhood of Dunedin and other places; and during the middle miocene period Otago was again slightly raised above its present level, so that no rocks belonging to the Ahuriri formation could be deposited here. This elevation was probably not very great, for the Ahuriri formation occurs in

* Reports of Geological Explorations, 1872-3, p. 44.

the Waimakariri Valley, in Canterbury, at an elevation of about 3000 feet above the sea, and if the Province of Canterbury was so much depressed at that time, Otago is not likely to have been much elevated. It was, however, sufficient to cause the Oamaru formation to be considerably denuded, and the Pareora formation now lies, as in the Shag Valley, in the hollows that were then formed in it.

During the upper miocene period the whole of the South Island was considerably depressed, and, if I am right in supposing that Mount Prospect near Lake Te Anau is composed of rocks of that age, Otago must then have stood at least 3246 feet lower than at present.

No marine rocks of older Pliocene age are known in any part of New Zealand, and consequently I infer that at that time the whole country stood at a higher level than at present; but at Wanganui there is a bed of blue clay containing marine shells, of which about 24 per cent. are now extinct, which, therefore, we must refer to the newer Pliocene period. Also in many places round the coast of New Zealand, such as Oamaru, Mataura, Wanganui, Taranaki, Cape Kidnappers, &c., we find pleistocene deposits containing marine shells, in some of which all are still living, and in others there are from 5 to 10 per cent. of extinct forms. Consequently there can have been no general elevation of the land extending over a long period since Pliocene times.

That the subsidence which followed this last elevation was continued until Otago stood at a much lower level than at present, and that it was subsequently followed by an elevation, which may probably still be going on, is proved by many facts. The silt deposit at Oamaru, already described, proves conclusively a subsidence in pleistocene times to an extent of at least 500 feet, and consequently a subsequent elevation of a like amount. At Bushy Park, south of Shag River, a raised beach occurs at about 100 feet above the present sea level. On the seaward side of the Dunedin Peninsula, High Cliff, which is about 900 feet high, presents a remarkable series of five or six terraces (fig. 18) apparently due to marine denudation at various levels, but I have not been able to examine it closely, and it is possible that in so hard a rock these terraces may have kept their shape for a long time, and they may have been formed during pauses in the movement of a previous subsidence, or they may be caused by harder ledges of rock. For these terraces and even cliffs are not by any means of universal occurrence on the east coast of Otago, the hills sometimes sloping gradually down to the sea. The best example that I know of

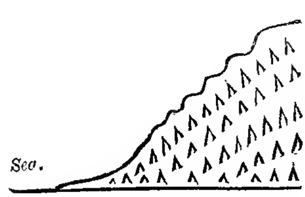

Fig. 18. High Cliff, Dunedin.

this is at Quoin Point, between the Taieri and the Tokomairiro (fig. 19), which exhibits a very characteristic plain of marine denudation.

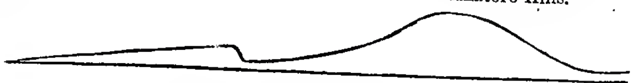

Fig. 19.—Quoin Point.

The Southland plains are distinctly terraced, and as Dr. Hector remarks are "marked by ridges which doubtless indicate the successive channels which were formed by the Mataura and Oreti rivers at the time they poured their waters into an extension of the present bay, prior to the last elevation of the land."* The network of gravel beds which surround the Hokanui and Moonlight ranges also shew evidence of marine action, for it is impossible that the alluvia of the Mataura, the Oreti, and the Jacobs River should all join one another with gradual slopes behind the seaward range of hills, without the intervention of some uniform widely acting cause, such as the sea; and we have further evidence of this action in the flat topped beds of eocene limestone in the Waimea plains. This would show that the land here has been lately about 600 feet lower than at present, which corresponds very well with the height of the silt formation at Oamaru. The chain of small islands between Paterson's Inlet and Ruapuke are also quite flat-topped, the result evidently of marine denudation. They are between 140 and 200 feet high.

In the West Coast Sounds nothing perhaps is more striking to the geological eye than the contrast between the immense, almost perpendicular, cliffs found up the Sounds and the absence of any high sea cliffs between them. This certainly implies that the land must be moving either up or down, and constantly therefore presenting a new line of action to the surf. For if the land had been stationary, the furious swell of the Pacific Ocean, impelled against the same line of coast by the almost constant succession of westerly gales, must have long ago eroded them back so far that an iron bound coast line of high cliffs would have been formed all along that part of the coast where the mountains approach close to the sea. But this is by no means the case. At all the headlands between the Sounds the spurs of the mountains, covered with bush, slope at angles of between 25° and 50° to the sea, and only a line of low cliffs is seen at their base. (See fig. 21.) That this movement is one of elevation there are several proofs.

On Coal Island, just opposite Otago's Retreat, there is a sea worn cave situated about 12 feet above the present sea level, and Dr. Hector mentions others at elevations of from 10 to 20 feet. Off Green Islets there is a remarkable rock, between 90 and 100

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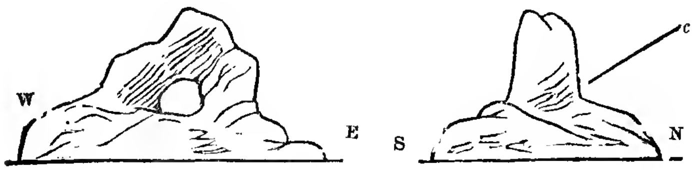
*Geological Exploration of the West Coast of Otago, p. 441.

feet high, which at a height of about 40 feet is cut into a step-like terrace all round. (See fig. 20, *a* and *b*) On the east side this terrace is cut into two steps (fig. 20, *a*), and just on a level with the terrace the rock is pierced completely through in a north and south direction. It is quite evident that both the



a *b*

Pierced Rocks of Green Islet.

Fig. 20. Pierced Rock off Green Islets.—*a*, view looking north; *b*, view looking west; *c*, position of hole.

terrace and the hole were caused by marine denudation when the land stood 40 feet lower than at present. The low land east

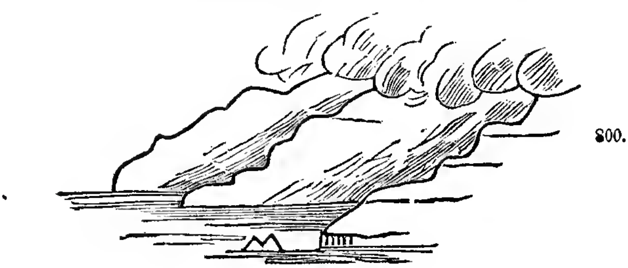


Fig. 21. Entrance to Doubtful Sound from the north.

of Windsor Point is also distinctly terraced. These terraces can be easily recognised, but I was not able to estimate their height.

The entrance to Doubtful Sound is also distinctly terraced on both sides, (fig. 21), and I estimated the highest to be about 800 feet above the sea level.

On the other hand Dr. Hector has brought forward the following evidence in favour of the view that these Sounds are at present undergoing subsidence. Speaking of the streams that run into Edwardson Sound, a branch of Chalky Inlet, he says "the flats along the lower parts of these streams are true valley deposits, such as may be seen in any mountain valley, formed by the gradual change of the water course from side to side; and as I did not discover any remains above high water mark of the brackish water deposit with estuarine shells, which is now slowly filling up the basin, or any trace of terraces round the mouths of the rivers, I conclude that the land at the head of this sound, unlike most parts of the New Zealand coast, is not rising; and the consideration of the

nature of the falls almost demonstrates that it is, on the other hand, an area that is being submerged. The examination of the walls of the chasm through which the first mentioned river—[the north river at the head of Edwardson Sound]—falls—[the falls are 25 feet high, and the river falls into a pool in the chasm 36 feet deep]—convinced me that it has been cut by the action of falling water, which may have followed a pre-existing fissure. The rock is a granular quartzite, compact and close grained in texture, but still such a rock that can be slowly worn away by the mechanical action of running water. The depth of the rocky chasm below the fall must, therefore, of itself prove that the fall was once higher, and as it now falls to the sea level, as a necessary consequence it follows that the land must then have been more elevated." *

Again, speaking of the low neck of land, some 400 yards in length, between Cunaris Sound in Chalky Inlet and Last Cove in Preservation Inlet, he says: "This neck of land is quite low, but bounded on both sides by lofty and precipitous mountains. The torrents which descend from these flow into Preservation Inlet, and accordingly add to the eastern side of the isthmus by the quantity of subangular fragments of rock that they bring down. * * * The absence of the characteristic terraces which mark the existence of a 'col,' or ancient strait, was a further proof that the coast line here is not rising, as in a situation like this they could hardly fail to be present." (l. c. p. 452.)

This is all the evidence in favour of subsidence that I can find in Dr. Hector's Report, and I do not think that it has anything like the weight of that previously adduced in favour of elevation. In such steep-sided ravines as are these sounds, no deposits form along the sides except at the mouths of streams, and this, together with the heavy rains that are constantly falling, are quite sufficient to account for the absence of any brackish water deposit with estuarine shells above high water mark. For if formed on the sides they would be all washed down, and if formed at the mouths of the streams they would be at once either washed away or covered up with debris. Terraces could not be expected close to the mouth of the rivers, but only high up them; because, as the land rises, the mouth of the river is constantly advanced at the sea level, and the terraces are cut out higher up where the mouth used to be. Dr. Hector describes the flats along the lower parts of the streams as "true valley deposits;" but these streams are constantly bringing down gravel and boulders of all sizes, which cover up the estuarine deposit. The flats at the head of Bradshaw Sound, Bligh Sound, and Milford Sound, which are all that I was able to examine, I found to consist of fine mud and sand which had evidently been deposited in quiet water, and it was quite different from the material now being brought down by the streams, and which covers up the

* Geological Exploration of the West Coast of Otago, p. 451.

mud deposit higher up the stream. I certainly did not notice any terraces, but the flats at the mouth of these streams are covered with such a dense impenetrable vegetation, that exploration far from the river bank is almost impossible. The opinion that I formed after an examination of these flats was quite opposite to that of Dr. Hector, for I thought that they showed evidence of elevation.

The deep pool in the chasm, mentioned by Dr. Hector, has, no doubt, like the sounds themselves, been formed when the land stood at a higher elevation than at present, but I do not think that the hole necessarily implies recent subsidence, for its shape might have been preserved below the water for an immense period of time. With regard to the last evidence brought forward by Dr. Hector, viz., the absence of terraces on the low neck of land between Chalky and Preservation Inlets, even if we grant that terraces are characteristic of a col, which, however, I am not prepared to do, still, they could hardly be expected in this case, for the tidal current at the head of these sounds is very slight, and ever if a terrace had been cut, it would have been at once obliterated by the immense quantity of debris that falls from the lofty and precipitous mountains on either side of the col.

The Rev. R. Taylor, in his "New Zealand and its Inhabitants" (London, 1855), states that earthquakes in 1826 and 1827 so altered the form of a small cove, called "The Jail" by the sealers, about 80 miles north of Dusky Sound, that it could hardly be recognised. The cove became dry land, and trees were seen under water near the coast, having probably been carried down by landslips into what was previously deep water.

It has been already mentioned that all the river valleys in the interior exhibit a remarkable series of alluvial terraces. These terraces are generally supposed by geologists to be caused by the rivers rapidly cutting down their beds during elevation of the land, but as Dr. Haast has stated* that there is another agency by which alluvial terraces are formed, "namely the retreat of the river sources to higher and more distant regions,"† it is necessary for me to show that he is mistaken on this point.

When the land is stationary or sinking, the lateral denudation on the sides of the valley is as great as the vertical denudation, and consequently no terraces would be left. But if by any combination of causes a terrace should be left, it would by this process be a rock terrace, and not formed of alluvium. Dr. Haast's theory also would not account for terraces in the lower portions of the rivers, for here.

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* Report on the formation of the Canterbury plains, p. 14. The other reason given in this Report to account for terraces, viz., "The permanent diminution of their (the rivers) waters through changes at or near their sources," need not be discussed, for it would act in exactly the opposite direction to that supposed by Dr Haast.

† Trans. N. Z. Institute, vi., p. 423.

when the land is stationary, the constant level of the sea prevents the rivers from deepening their channels, and when the land is sinking, it is obvious that all rivers must be filling up their old beds throughout the whole of their lower portions. If Dr. Haast was right in his surmise, we should see terraces equally well developed in all mountainous countries, and those of Wales and Switzerland ought to be as remarkable as those of New Zealand, which is very far from being the case.

The evidence, therefore, appears to me to show that the latest movement in Otago has been one of upheaval, both on the east and and west coasts, and that the amount of this upheaval has been, at least, 500 feet.*

Glacier period.—In the last section I adduced abundant evidence to show that the Otago glaciers formerly extended much further than they do now, and this could only have been caused either by a much colder climate than at present, or by the land having stood at a much greater altitude.† Now, although we have proofs of the former great extension of our glaciers, we have no proof whatever that they descended nearer to the sea level than at present, although they probably would do so when they were larger, and had larger supplies of snow. But there is no proof whatever that they reached the sea. There are no stratified moraines nor boulder clay to be seen; no marine shells have been found in any of the glacier deposits, even when, as in the case of the moraine near the mouth of the Taieri, they are now at the sea level. Also, there are no signs in any of the newer pliocene and pleistocene deposits of any change in the fauna that would indicate a colder climate. On the contrary, the pliocene and pleistocene beds at Wanganui contain recent species of shells that cannot now live south of Cook Strait, while the cold that would be necessary to bring back our glaciers to their former dimensions would be sufficient to exterminate throughout New Zealand all those shells that cannot now live on the coasts of Otago. We find, however, that some of them have existed in New Zealand ever since the upper miocene period. We have, therefore,

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* Captain Fairchild informs me that a Weka (*Ocydromus hectori* (?),) is found on the Solanders; consequently, this island cannot have been entirely submerged since it was separated from New Zealand. It is 1,100 feet high, and an elevation of 400 feet would connect it with New Zealand.

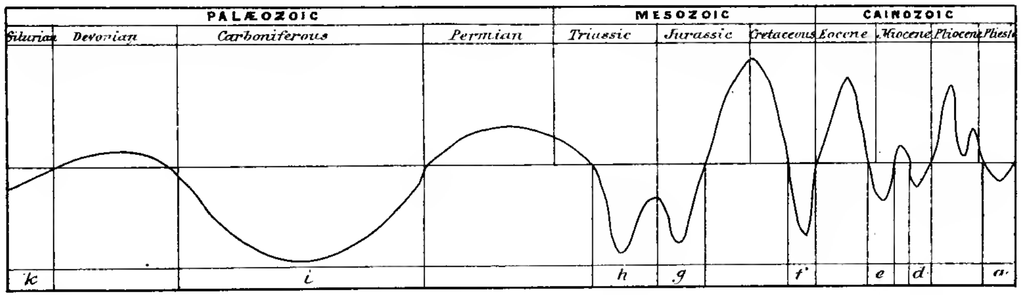
† Dr. Hector and Dr. Haast have suggested that the mountains may have had a more plateau-like form, and consequently, collected more snow during our glacier period than now. This, no doubt, would tend to increase the size of the glaciers, but we must remember that the New Zealand Alps have been undergoing denudation ever since the jurassic period, and that in the upper eocene period, many of the valleys in them had been hollowed out nearly as deeply as now, consequently, during the comparatively short period that has elapsed since the date of our last great glacier period, denudation cannot have affected the shape of the mountains to such an extent as to make it worth while to take this cause into consideration.

no trace of a cold or glacial epoch, and we are obliged to fall back on elevation of the land as the main cause of the former extension of our glaciers. And, as we have already seen that New Zealand has not stood at a higher level than at present since older pliocene times it is to that date that we must refer our last glacier period.

If we now turn for confirmatory evidence to the glacier deposits themselves, and to the older alluvia, we find that the external forms of the older moraines are almost entirely obliterated, as for instance that at the junction of the Lindis with the Clutha, and that at Black Mount; while that near Taieri Mouth has not only lost its external shape, but is almost entirely covered on the seaward side by what appears to be marine gravel. Others of a rather later date have also been much modified as at the southern extremities of Lakes Wakatipu, Wanaka, and Hawea. We also find that the polished surfaces and striæ have completely, disappeared in places where we know that ice must once have passed over. In some places, as near Queenstown, the rounded, smooth surface still remains, but in others not only has the polishing and grooving been obliterated, but subsequent weathering has so altered the once "moutonneés" surfaces as to make them quite unrecognisable, as in the west coast sounds; and there are places in the Maniototo and Dunstan districts, where masses of rock ten or twelve feet in thickness have been removed since the ice passed over them.

This great amount of weathering may in part be due to the nature of the rocks, but the modifications of the moraines certainly indicate their great age, and a study of the older river alluvia leads us to the same conclusion. For instance, I have pointed out that in the Shotover there are two distinct river channels separated by a sharp ridge of rock, and that the older channel is filled with gravel (see fig .16). Now it is evident that no glacier can have come down the Shotover since the older channel was filled up, or it would have ploughed all the gravel out again and rounded the sharp ridge between the two. Indeed the V-like form of the older channel, as well as the gold found in the bottom of it, prove that it was cut out by the river, and not by a glacier, which are known not to cut sharp V-shaped but round bottomed U-shaped valleys. Remembering, therefore, that rivers deepen their beds when the land is rising and their velocity increasing, and fill them up when the land is sinking and their velocity consequently dimiuishing, we see that the Shotover supplies evidence that since any glacier came down it, the land has been elevated, then depressed, and subsequently elevated again. And if to this we add the first depression which caused the glacier to retire, we have two depressions and two elevations subsequent to the great extension of the glaciers. The same conclusion will be arrived at by a study either of Lammerlaw Creek, at Waipori, or Few's Creek, at Lake Wakatipu.

DIAGRAM OF OSCILLATIONS OF LEVEL IN OTAGO



a . Pleistocene
d . Pareora formation
e . Oamaru formation
f . Waipara formation
g . Putataka formation
h . Maitai formation
i . Kaikoura formation
k . Kakanui formation

If also the old lake basins in the interior have been hollowed out by glaciers,* it is evident that an immense length of time must be allowed for filling them up.

Consequently we have proofs not only of the great length of time that has elapsed since the greatest extension of the glaciers took place, but also of a second elevation, and consequent second advance of the glaciers, which, however, was less than the first, as the ice did not a second time come down the Shotover. These two elevations we may with much probability place between the Pareora and Wanganui formations, and between the Wanganui and pleistocene deposits respectively; the earlier elevation being the greater and the longer continued. The New Zealand *glacier* period has therefore nothing in common with the *glacial* period of the northern hemisphere.

If now, in order to assist the memory, we throw the various oscillations in level that Otago has undergone into the form of a diagram, as in Plate II., where the central horizontal line which represents the present elevation of the Province, is divided into spaces proportional to the length of the different geological periods, we see that these oscillations have been more numerous and more extensive since the middle of the jurassic period than before it; and that since that period there have been three main upheavals, and two minor ones, or five in all; of which the first represents the period of the antarctic continent, and the last but one the period of the greatest extension of our glaciers. It is, however, probable that we had a glacier period during each of the main upheavals, and indeed we have proofs, as I shall show in the next section, that there were large glaciers in Otago during the middle, or eocene upheaval.

* The proofs of this will be given in the next section.

SECTION VI.

Surface Geology.

Having described the geological structure of the Province, and probable oscillations of level that it has at various times undergone, we are now in a position to discuss its surface geology, or in other words to attempt an explanation of the various causes that have brought about the surface contours of the country; and although it cannot be expected that in the present incomplete state of our knowledge all the numerous and complicated problems presented to us in Otago can be satisfactorily resolved, yet if our observations on the geology of the Province, and the deductions drawn from them are in the main accurate, then the errors that we may fall into in attempting the solution of some of these physiographical puzzles will be errors of detail only, and not errors of principle; and further and closer observation will no doubt enable us to correct them.

It would be out of place in this report to discuss those features that are common to all countries, such as the origin of valleys, plains, &c., for this will be found in any good text book of geology, and it is here only intended to mention those peculiarities in the rivers, valleys, &c., in Otago that require special explanations, or those points which relate specially to the gold-bearing drifts* of the Province. There is, however, one point, which as it is still considered "sub judice" by some geologists, and as it will have to be constantly referred to in the following pages, must be briefly discussed here. I mean the origin of lakes lying in rock-basins. By the term "rock-basin," is meant a hollow in the solid rock, the margin of which is on all sides higher than the bottom. These rock basins, when on a large scale, can only have been formed in one of two ways, viz., either by unequal elevation or subsidence of the area, or by the erosion of ice. A glacier hollows out a rock basin in this way. The terminal moraine at the end of a glacier covers up the rocks all across the valley, and prevents further

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* The term "drift," or "gold drift," has come into such general use in the Australasian colonies for gold-bearing alluvial deposits, that I think it better to use the word here; and it must not, therefore, be thought that by "drift," I mean only glacial or ice born deposits, which is the original and more correct definition of the term.

denudation taking place at that point. But above it the moving ice still keeps wearing away the rocks below it, and if this action is sufficiently long continued the slope of the valley down which the glacier is moving may in time be reversed; the cohesion between the upper and lower portions of the ice enabling the upper portions, which still retain their original slope, to drag the lower portions up hill along with them. And when the glacier melts away a rock basin is left behind, which forms a lake.

If now we turn to the lakes and old lake basins in Otago, we find that all the present lakes lie in rock basins, for they are very deep, while the rivers draining them run over rocky beds. At Cromwell the lignite has been worked to 80 feet below the river level, while the river itself runs over rock in the Dunstan Gorge. The Upper Taieri Lake proves the same thing for the Maniototo Plains, and although I do not know of any sinkings that would prove the Manuherikia Valley to be an old rock basin, we cannot doubt but that it is similar to all the others. Now in order that these lakes and old lake basins might be produced by unequal movements of the earth's crust, the land north of Lakes Te Anau, Wakatipu, Wanaka, and Ohau, and the Manuherikia Valley must have been depressed, or that south of them must have been elevated, and as these lakes are very deep, the movement must have been considerable On the contrary, in order to account for the old lakes of the Ida-burn Valley and the Maniototo Plains, the land north of them must have been elevated, or that south of them depressed; and as the Ida-burn Valley lies close alongside of, and parallel to the Manuherikia Valley, it is evident that the flexures in this part must have been very abrupt. Now not only are no signs of these movements to be found in the geological structure of the district, but we must also remember that owing to the great thickness of the earth's crust, it is impossible that folds of this nature could take place in any one district without a large area being similarly affected. But we know, from the horizontal disposition of the older tertiary rocks in Otago, that no such disturbance has taken place since their deposition; and as the lake basins must have been formed considerably after that date, it follows that in Otago they cannot be due to unequal movements of the surface. On the other hand glaciers in some cases still occupy the heads of the valleys in which the lakes lie, and in most of them there is ample proof that glaciers once filled the valleys now occupied by the lakes; consequently I shall in future assume that all the rock basins in Otago, whether filled with water, or with clay and gravel, have been hollowed out by ice.

Valley of the Waitaki.—That the Upper Waitaki Plains, through which the Ahuriri River now flows, once formed part of a lake connected with Lakes Ohau and Tekapo is evident. Whether the Ohau glacier at one time extended south across the present

valley of the Ahuriri, and into the low pass between St. Bathan's and the Hawkdun range; or whether the southern portion of the basin was hollowed out by a glacier descending down the valleys of the Upper Ahuriri and the Omarama and, together with the Ohau glacier, emptying itself into the Waitaki by the present outlet, I am unable to say. But I think there can be no doubt that the lower part of the valley of the Ahuriri has been cut since the disappearance of the glacier. The rocks in its valley are all sharp and jagged, and I saw no moraine in any part of its course, nor in the Waitaki, below where the Ahuriri joins it.*

That the lake once stood at a much greater height than at present, is proved by the Longslip hills, which are formed of lacrustive deposits, and rise through the shingle plain to a height of 200 or 300 feet. These hills form a line that runs nearly in the longitudinal axis of the plain, but is broken through in several places by streams, such as the Quail-burn, which cut straight through them to join the Ahuriri. These plains could not have been formed by the present rivers. Another important peculiarity is that they have two outlets, one by the Ohau River, the other by the Ahuriri; and as under ordinary circumstances no lake can have more than one outlet, some special explanation is required in this case. The following appears to me to be the most probable. After the first retreat of the glacier, a lake was left which overflowed down the Ohau River, but at a considerably higher level than at present. This lake was gradually drained, and the Ahuriri River running on the north side of the Longslip Hills, and the Omarama on the south side, both joining the Ohau River, they first wore down the lacrustine deposits on either side of the Longslip Hills and then deposited the shingle plains. Afterwards the glaciers of Ohau and Tekapo again advanced, and the latter blocked up the exit by the Ohau River; this caused a lake to be again formed over the southern parts of the plain, which overflowed down the present course of the Ahuriri. This lake was drained nearly to the level of the Ohau River before the glaciers retreated again, and while this was in operation, gaps were formed in the Longslip Hills, through which the new drainage system took place. When the glaciers at last retired the terminal moraines, and the gravels that the glaciers had pushed up before them during their second advance, threw the streams flowing from them back into their old channel, and thus separated them from the Ahuriri. It will be noticed that this explanation requires a double advance of the glaciers, the second being less than the first, which as we have already seen was most probably the case.

Further down the Waitaki, the outlier of older tertiary rocks

* Dr. Haast, in a paper in the Quar. Jour. Geo. Soc., 1865, p. 135, mentions an Ahuriri glacier 25 miles long, and a Waitaki glacier 78 miles long, and states that traces of the Waitaki glacier are still visible far down the river, but he gives no proofs of these assertions.

found at Big-gully Creek, appears to occupy another small rock basin in the valley of the river, which must have been hollowed out by an eocene glacier. The importance of this inference will be seen when we come to speak of the Blue Spur.

It is also evident that the Waitaki river existed in the lower eocene period, but that at that time, after passing the Maruwhenua, it flowed through the present valley of the Waireka.

Valley of the Shag River.—This valley, although not very large, is very old, and is particularly interesting, as we can fix the date of its formation to have been in the eocene period. The proof of this is that the upper cretaceous rocks of the Horse ranges (Waipara formation) form one side of its valley, while lower miocene rocks (Oamaru formation) are found lying horizontally in the centre. The valley, therefore, must have been scooped out between the dates of the Waipara and Oamaru formations. At this time it extended into the Kyeburn, as proved by the marine tertiary rocks found near the coal mine, and it probably took its rise in Mount Ida. The eocene Shag River was therefore considerably greater than the present one.

Subsequently, during the upper eocene and miocene periods, the valley was submerged and filled up with marine and volcanic rocks, which were afterwards partly eroded out again during the older pliocene upheaval; while at the same time the upper part of the valley, as far as the hard balsaltic rocks of the Houndburn, was worn away by the Upper Taieri glacier, and formed into part of the basin that was ultimately to become the Maniototo plains.

Old Lake Basins of the Interior.—That the Maniototo plains, the Ida-burn valley, and the Manuherikia Plains, were once lakes that have been filled up, is proved by the nature of the rocks that fill them, and the occurrence of fossil fresh water mussels at Clyde, and Mainototo Plains; and I have already given my reasons for assuming that they were hollowed out by ice.

The general configuration of the surrounding mountains shows that the Maniototo Lake was chiefly formed by the Upper Taieri glacier, and Ida-burn valley by the Pool-burn glacier, both these glaciers flowing north. Also the rounded form of the low narrow ridge of schist which separates the two where the Rough Ridge joins the spurs of Mount Ida, makes it appear probable that the Maniototo glacier joined that of the Ida-burn at that point, and that both together flowed round Blackstone Hill into the Manuherikia glacier. There is also some confirmatory evidence on this point. In the neighbourhood of Naseby large quantities of boulders of a white or pinkish highly metamorphosed quartz conglomerate occur, and blocks of the same rock are also common in the Maruawhenua on the other side of the Kakanui mountains, and are occasionally found as far down as the Awamoko. I have not been able to find this rock in situ, but from the dis-

position of the boulders I think that it will probably be found somewhere between Mount Ida and Kyeburn Peak. Now boulders of this conglomerate are found all down the valley of the Manuherikia as far as Clyde, and as the streams do not run in that direction now, it follows that they must have been taken into their positions by a different drainage system to the present one.* If this view is correct, the terminal moraine of all these glaciers would have been at Clyde and Alexandra, and the river running from it would have flowed down the valley of the Clutha. I have already said that I saw no trace of a moraine in this position, but it must be remarked that the mountains from which these glaciers would have been fed are round-backed, and tolerably equal in altitude; consequently they would be almost entirely covered with snow. Also the Clutha has had plenty of time to remove any moraine that might once have existed there.

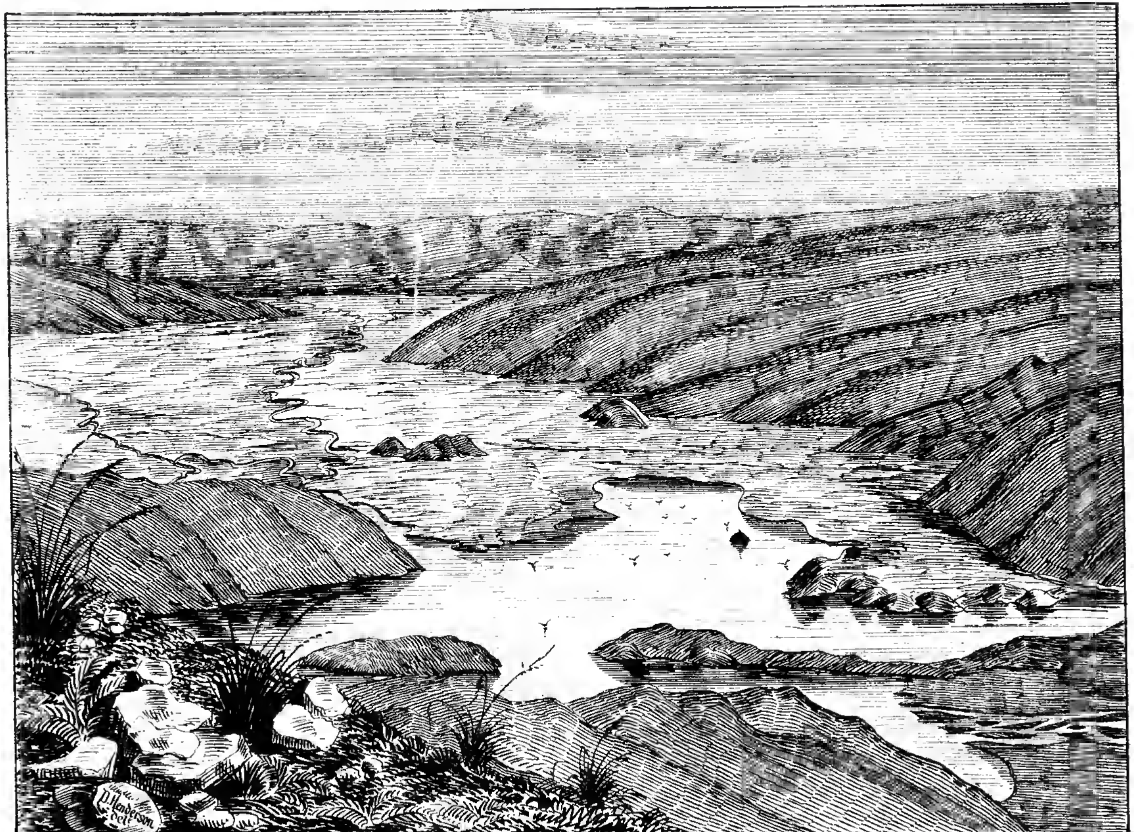
We have now to try to account for the change in the system of drainage that took place after the disappearance of the glaciers, and which caused the Maniototo Lake to overflow into Strath-Taieri, and the Ida-burn Lake to break through the Raggedy Range near Black's.

When the land began to sink, and the glaciers to retire, those of the Maniototo and Ida-burn would retreat much faster than that of the Manuherikia, as they were fed by the snows on lower ranges of mountains which are of nearly equal altitude; and this difference would be the greater if, as is probable, the Manuherikia glacier was a continuation of the Ohau glacier. If now we assume, as we reasonably may, that the Maniototo and Ida-burn glaciers had been greatly diminished, or altogether disappeared, while the Manuherikia glacier was still continued as far as Blackstone Hill, lakes would be formed in the Ida-burn and Maniototo valleys, separated from one another by the Rough Ridge; and if the ice at Hills Creek was sufficiently high, these lakes would be dammed back until they overflowed at the lowest place along their margins, which in the case of the Maniototo, would be into Strath Taieri, and in the case of the Ida-burn, into Manuherikia, above Blacks. Gorges would then be cut down in these plains which, by the time that the Manuherikia glacier had retreated to the Hawkdun Mountains, might be sufficiently low to continue the drainage.

To test the truth of this conjecture, it will be necessary to compare the levels of the tops of the gorges where the Taieri and Ida-burn quit their plains, with the lowest part of the ridge dividing them, and ascertain what thickness of ice would be required at Blackstone Hill to cause the lakes to overflow there. It will be noticed that this hypothesis makes no mention of the second advance of the glaciers. This is because the second elevation was not suf-

* The boulders containing tertiary fossils found at Alexandra may also have come from the upper Shag Valley.

PLATE III



From a Sketch by J. Buchanan.

OUTLET OF WANAKA LAKE.

ficiently great to form glaciers of any size in the Lammerlaw Range, which is quite in accordance with our supposition that these glaciers had retired while the Ohau glacier was still at Blackstone Hill, because, as we have already seen, the second elevation was only supposed to have made the Ohau glacier advance so far as to block up the Ohau River. It also explains why these old lake basins are entirely filled up, while those situated more in the mountains, having been re-excavated by the second advance of the glaciers, are still unfilled.

The great length of time that has elapsed since the ice passed over this district, is shown by the extraordinary way in which the rocks are weathered. At a distance these hills look quite smooth and rounded, but on closer inspection the surfaces are seen to be formed of numberless projections of solid rock, some ten or twelve feet high, with grass growing between them. It is to this that many of the ranges owe their very suggestive names, such as Knobby Range, Raggedy Range, Rough Ridge, Rock and Pillar, &c. This very peculiar style of weathering is different from anything that I have seen elsewhere, and I can offer no sufficient explanation of it; but I would remark that it is confined to the dry inland district, and gradually disappears towards the coast.

Valley of the Upper Clutha.—The old lake formed by the united glaciers of Wanaka and Hawea appears to have passed Cromwell, and extended up the Bannock-burn and Fork-burn Creeks, the outflow of the river from the glacier being probably into the Frazer River, and so into the Clutha. Not only does the shape and position of the old lake basin indicate this, but there are also reasons for concluding that the Dunstan gorge, through which the river now flows, was not then in existence. In the first place, the abruptness and narrowness of the entrance to the gorge at Cromwell shows that it has never been the outlet for a large body of ice; and in the second place the lignite deposits under the township at Clyde must have been formed in still, shallow water, which could not have been the case if the Clutha then rolled through the gorge in the way it does now.

It has already been said that lakes Hawea and Wanaka are terminated by low moraines, which pass gradually into the broad gravel plains lying beyond them.—(See Plate III.) The peculiar shape of these moraines may perhaps be owing to the glaciers in their second advance having pushed the gravel beds before them. The plains themselves also are of interest as bearing on Dr. von Haast's theory of the formation of the Canterbury plains by rivers running from glaciers. The glaciers of Hawea and Wanaka, separated by a range of mountains, present a parallel case to the glaciers of Waimakariri and the Rakaia separated by the Malvern Hills, and the plains in Otago have certainly been formed in the way suggested by Dr. Haast. But while the Canterbury plains on

either side of the Malvern Hills are within a few feet of the same level, those of Hawea and Wanaka, although much closer together, differ in height by more than 200 feet, thus showing the great improbability of the level plains of Canterbury having been formed in the same way.

Lake Wakatipu District.—I have already said that the moraine that circles round the end of Lake Wakatipu behind Kingston, which is one of the best marked moraines in Otago, proves that the lake was once occupied by a glacier; and I have already mentioned that a lateral moraine is found in places along the east side of the lake, which moraine is in part composed of rocks, such as sandstone and greenstone tuff, which only occur on the western side. Now these sandstone boulders can be traced from Queenstown as far as Frankton, where they are covered up by the debris brought down by the Shotover, and I have not been able to find any more of them further down the Kawarau until we come to within a few miles of Cromwell, where sandstone boulders again occur, that have come down from Lake Hawea. From this we must infer that the glaciers that descended the Arrow and Shotover valleys did not continue down the Kawarau, for they would have taken the sandstone boulders with them, but that they joined the Wakatipu glacier at Frankton, and then both together went down to Kingston, and on to Athol and the Dome Pass. When afterwards this glacier had retreated to Kingston, a lake was formed between there and the Dome Pass, which overflowed into the Nokomai, and cut the Mataura Gorge opposite Athol. Previous to this the Nokomai had been the source of the Mataura.

While the main glacier of the Wakatipu was retreating, the smaller ones of the Arrow and Shotover were doing the same, and they were unable to reach Frankton long before the main glacier had retreated so far. Consequently a lake would be formed between Frankton and Arrowtown, which, dammed back by the ice of the Wakatipu glacier, overflowed into the Kawarau, cutting a gorge through what is now known as the Arrow Bluff, which was previously the line of watershed between the Arrow and the Kawarau. By the time that the Wakatipu glacier had retreated as far as Queenstown, this gorge must have been cut so deep that it was lower than the lowest part of the moraine at Kingston, and consequently the whole of the drainage of the lake took this channel. Lake Hayes was afterwards separated from Lake Wakatipu by the detritus brought down by the Shotover.

It must not be supposed that this method by which glaciers alter the former drainage system of a country is not paralleled by cases occurring at the present day, for the Lake of Moril, in Switzerland, is now held back by the ice of the Aletsch glacier, so that in floods it overflows into the Rhone by another channel, and if the present condition of things is continued long enough, this

channel will be cut sufficiently low to drain the whole of the lake that will be left when the Aletsch glacier melts away.

Tuapeka District.—Seated on the top of the saddle that divides Monro's from Gabriel's Gully, is a deep cup-shaped hollow in the schist rocks which has been filled up much higher than the present lips of the cup by gravels cemented into a hard blue conglomerate. This is the Blue Spur, famous for the immense quantities of gold that have been derived from it. On close inspection this hollow is seen to have been an old mountain tarn with smooth polished sides, which have, however, now decomposed into blue clay to a variable depth of from two to six inches. Although I could detect no striæ on the sides of the hollow, I have no doubt but that it was excavated by a glacier. This old rock basin is filled up with beds of conglomerate that dip to the east—(Fig. 6)—and as a rule the stones in the conglomerates get smaller toward the east, which, together with the direction of the dip, prove that the old tarn was filled up from the west. The conglomerates consist in great part of pebbles and subangular blocks of green quartzite and a dark purple jasperoid slate with quartz veins, which rocks do not exist nearer than the Tapanui mountains, west of the Clutha River. South east of Lawrence also, several other patches of conglomerates are found at the Blue Lead, Waitahuna, at Manuka Creek, &c., all of which probably mark the position of an old valley which extended from the Tapanui mountains through the Blue Spur to Kaitangata. No appearance of such a valley can, however, be seen at present, and its supposed course is now crossed at right angles by the Clutha, and by the Tuapeka and Waitahuna rivers. Consequently this old river must date back to a time previous to the formation of the present valleys ; and as we have already seen that the Clutha received the drainage of the pliocene glaciers of Maniototo, Ida-burn, and the Manuherikia, we must place the existence of the Blue Spur glacier during a still earlier upheaval ; that is to say, we must refer it to the eocene period. The auriferous conglomerates, therefore, would have been poured by the river into the old mountain tarn after the retreat of the glacier, caused by the subsidence that took place previous to the deposition of the Oamaru formation. There is nothing extravagant in these suppositions, for in the valley of the Waitaki we have collateral proof that eocene glaciers existed in New Zealand, and that gold existed in the rocks during the eocene period we have proofs in the auriferous sandstone of the Shag River—(ante p 17)—and in the auriferous conglomerates over the coal at Coal Point (ante p. 48.)

Lower Taieri and Tokomairiro District.—It has been already mentioned that a valley extends from the Silver Stream, behind Dunedin, through the Lower Taieri plain, Waihola Gorge, and Tokomairiro Plain to the mouth of the Clutha. The old moraine on the south east side of this valley, between the Taieri and the

Otokaia has also been described. Now it is evident in the first place that this valley existed in the eocene period, and that its estuary was filled up by the Tokomairiro and Kaitangata coal formation in the lower miocene period; and secondly that the valley as it now exists was again hollowed out when the land was elevated, for the tertiary rocks are left on either side of it at Waihola Gorge and Tokomairiro. It appears therefore probable that during the greatest elevation of the land in the older pliocene period, glaciers came down Strath Taieri (it must be remembered that the gorge between Strath Taieri and the Maniototo Plains was not at that time in existence), which being met by another large glacier coming down the Waipori, turned eastward, and had its terminal moraine between the Taieri and Otokaia. The river running from the end of this glacier appears to have cut down the gorge between Taieri mouth and the bridge, and when the glacier retired, this channel took the whole of the drainage of the Taieri, now reinforced by the addition of the Maniototo Plains to its catchment basin. We must also remember that since this period the whole of the valley up to a height of about 500 feet must have been submerged below the sea.

Summary.—In this section we have seen that since the last great extension of our glacier system, the old lakes of Maniototo, Ida-burn, Manuherikia, and Upper Clutha have been filled up by debris brought down by streams; that the surfaces of the rocks that were formerly covered with ice, have been weathered to a depth of 10 or 12 feet; and that the gorges of the Kawarau, Dunstan, Mataura, and Upper Taieri have been formed. So that in many places the drainage system of the Province has been completely altered since that time, and if to this we add the evidence adduced in the last section, viz., the alteration in the external forms of the older moraines, the older river channels being filled up with gravels, and the depth to which the rivers have cut their new beds, we can have no hesitation in placing the date of our last great glacier period far further back than the glacial epoch of the Northern Hemisphere. That all our lakes are not filled up is probably owing to the second advance of the glaciers which partially scooped them out again.

SECTION VII.

Economic Geology.

Under this head I propose to enumerate those substances that have a practical value to the immediate necessities of life, and which are more or less connected with geology. A full consideration in detail of many of them falls more into the department of the chemist than that of the geologist, for their exact value and uses can only be arrived at by analysis. The following account, therefore, only professes to describe what I have learnt from my own observations, and from the publications of previous observers, especially from the appendix A to the Jurors' Reports and Awards of the New Zealand Exhibition held in Dunedin in 1865, which contains a fund of information on the economic productions of Otago to which little has since been added.

Agricultural Geology.

This subject is one on which the opinion of a botanist would carry more weight than that of a geologist, for the nature of the crops that can grow in a district depends more upon the climate than upon the mineralogical composition of the soil. It is also well known that owing to a variety of complicated causes, the soil of most countries varies considerably over very limited areas, and so intricate are the various combinations thus arising, that no country has as yet produced a map exhibiting all the peculiarities of its soils; and it is probable that the advantage to be derived from such a map would by no means compensate for the expense of constructing it. I shall, therefore, confine myself to making a very few general remarks on the subject.

The soils of Otago, taken as a whole, are decidedly above the average in quality, and this appears to me to be owing to the great extent of mica-schist exposed at the surface, the decomposition of which has supplied more or less directly almost all the soil in the Province.

That this schist contains a considerable amount of lime, is proved by the incrustations of carbonate of lime found in nearly all

the caves in it, and the good quality of the soil derived from it is well seen in the Dunstan district, which is remarkably fertile when irrigated.

These mica schist soils occupy nearly the whole of the interior of Otago proper; but those of the Te Anau district and the northern part of Southland are derived from the decomposition of slates and sandstones. Around the east coast, and in the south-western part of Southland, a considerable extent of limestone soil occurs, and this on the east coast is often intermixed with the debris of basaltic rocks; a mixture which, theoretically at least, forms the finest soil in the world. The poorest land is found on the coal fields and on some of the trachytic rocks near Dunedin, but it is limited in quantity.

It is not the quality of the soil, but the mountainous nature of the country, that is the great drawback to agriculture in Otago, and this acts not only directly in the rocky and precipitous character of large parts of the Province, but also indirectly, by causing all the rivers to be mountain torrents, which have covered with gravel, and utterly spoilt large areas of what would otherwise have been fine alluvial soil. The gold miners are also now in league with the rivers, and we may feel sure that before many years are passed, considerable quantities of agricultural land will be either washed away or covered with "tailings."

Coal.

Although Otago does not possess any first-class coal suitable for steamers making very long ocean voyages, it is abundantly supplied with very excellent brown coal, lignite, and peat; all of which are very valuable for different purposes.

Peat.—Very good peat is found on many of the mountains, especially on the Rock and Pillar, and Rough Ridge. Its importance in a treeless country cannot be over estimated, and I am of opinion that some steps should be taken to ensure its being worked to the best advantage, for at present a considerable waste is going on by allowing inexperienced cutters to take what they like.

Lignite of pliocene age is found round the margins of nearly all the old lake basins, as at Kyeburn, Idaburn, Hills Creek, Welshman's Gully, Lawrence, Clyde, Cromwell, Bannockburn, Nevis, Cardrona, and Gibbstown. It no doubt exists in many other places in these basins, but so covered up by gravel as to be difficult to find. The second way in which lignite occurs is in the older river valleys that existed before the time of the great newer pliocene depression. Such are the lignites of the lower Mataura, at Waimea Plains, Waikaka, Mataura Falls, &c.; of the Clutha, at the Teviot; of the Shag River, at Glovers; and of the Waitaki, at Awamoko. In this division we may also place the lignites of Fairfax, and Lovell's Flat, near Tokomairiro. I have not heard of any

having been found up the Waiau, but it probably exists there. In the newer river valleys, such as the Lower Ahuriri, Dunstan and Kawarau Gorges, Oreti and Jacob's Rivers, it is not likely to occur, as these were not in existence during the great depression when the gradual diminution in the velocity of the rivers favoured the formation of swamps, and consequently the growth and accumulation of vegetable matter on their margins. The lignites near Invercargill, and at Orepuki, may have been formed as estuarine deposits very slightly above the sea level, or they may have been formed by swamps when the land was considerably higher.

These lignites vary very much in quality. Occasionally well preserved trunks of trees are found in them, and generally their vegetable origin is easily recognised by the naked eye; but occasionally they pass into a compact brown mass in which no structure is visible, and which cannot be distinguished from brown coal. They also often contain large lumps of fossil resin, or retinite, which is a proof that they have been formed to a great extent by the decomposition of coniferous trees; but I am not aware that any attempt has yet been made to determine the plants found in them. When this is done we shall be able to form a better opinion as to their origin.

The thickness of these seams is often very great, amounting to 30 feet in some places, but like all lignite beds, they are local and unconnected, and there is no certainty of any of them continuing far.

The following are the only analyses of these lignites that I have been able to find.

—	Totara Creek, Omaru.	Watahuna.	Tuapeka.	Idaburn.	Average.*
Water	13.40	11.06	16.80	11.60	13.75
Fixed Carbon	39.10	37.28	34.40	16.97	36.92
Hydro-Carbon	44.70	39.88	44.40	41.85	42.99
Ash	2.80	11.81	4.40	29.58	6.33

* Omitting Idaburn, which must have been a very bad sample.

These lignites always contain a considerable amount of sulphur, and give out a very unpleasant smell when burning.

Lignites belonging to the Pareora formation are found at Coal Creek in Shag Valley, and in the Pomahaka, and probably that at Kauroo, near Oamaru, is of the same age. I am not sure whether the lignite of Wharie Creek, in the Takatimu Mountains, should not be

considered as a brown coal, and I am also uncertain whether it occurs under a pliocene lacrustine deposit, or whether it is covered by rocks belonging to the Pareroa formation.

Brown Coal of eocene age is found in Big Gully Creek in the Waitaki, where it was worked in 1861 by Mr. A. Geddes, and at Green Island and Saddle Hill; at Tokomairiro, Kaitangata, and Coal Point; at Orepuki, and at Taylor's Creek, Morely Creek, and the Nightcaps in Southland. Thin seams of no value have also been found among the trachytes in Dunedin Harbour. The brown coal at Shag Point is of upper cretaceous age, while that of Preservation Inlet may be either eocene or upper cretaceous, probably the former. These localities include all the important coal fields of Otago, and I shall describe them subsequently. The coal in many of these fields is covered by marine rocks, and in this respect differs from the lignites already mentioned. It differs much in quality, but even the best is not first-class coal, its great fault being that on exposure to the weather it falls to pieces, and therefore it cannot be stored in large quantities, but must be used soon after extraction from the mine. Nevertheless it is a very valuable fuel, and well adapted for all household purposes, stationary engines, and river steamers. In Europe it is also sometimes used for smelting iron and for locomotives. It will also answer equally well for coasting steamers that do not require to lay in a large supply at a time. Its heating power is inferior to that of true coal, but this will be amply compensated for by its greater cheapness, and it will no doubt come largely into use throughout the Province when the railway system is more developed. The most economical way of burning it appears to be in a fire-box with an inclined perforated iron-plate instead of fire bars or a grate. The causes of the defects that I have mentioned are not well understood, although they are known to be connected with the amount of water in combination with the coal. They cannot be due simply to its age, as was formerly the general opinion, for in the valley of Zsil, in Transylvania, beds of real anhydrous coal occur, which are of tertiary age, but which have none of the defects of brown coal. In New Zealand also the eocene coals of the Bay of Islands and Whangarei are much superior to some of the cretaceous coal of Malvern Hills and Shag Point. Disturbance of the beds and subsequent drainage seems to have a very beneficial effect on coal. For instance the coal of Mount Hamilton, which is situated in a disturbed area, and near the top of a mountain, is far superior in quality to that of Shag Point which has been less disturbed, although both are of the same age. Again the coals of Kaitangata, Tokomairiro, and Morely Creek, which are elevated above the drainage level, are superior to that from Green Island, which is situated below the drainage level. These brown coal deposits differ from the lignites in being more regular in thickness, and in extending over large areas, thus enabling them to be mined

with greater advantage. Coal mining in the Province is at present a very simple affair, as the mines have only lately been opened, but every year will increase the difficulty, and it is very important that the mines should now be opened in the best possible manner so as to insure in future years the winning of the greatest amount of coal with the least expense. That some of the coal mines are not now being worked in a satisfactory manner is owing partly to the great expense for carriage, causing a limited local demand only, which would not justify any great expenditure of money in laying a mine out properly; but partly also, in my opinion, to leasing the coal pits for short terms, so that the lessee has no inducement to go to any expense in order to open out his mine properly, for the only effect of this proceeding would be to enable the lessor to raise the rent when the lease fell in; and it is more advantageous for the lessee to limit himself to getting the coal out at once as cheaply as possible, without any reference to the future. The first cause will disappear with the opening of the railways, but the second cause can only be overcome by either selling the coal mines or by leasing them for long terms, such as 99 years. The first method would, in my opinion, be the most advantageous where no monopoly is to be feared, as all along the coast line, or where several pits are situated in the same locality; for when a large sum of money has been sunk in buying a mine, the owners are not likely to let it lie idle. But in the interior of the Province, where there is no firewood, and where there are only one or two mines in the district, the 99 year's lease system would probably be the best, as the Government could then regulate the price of the coal at the pit's mouth.

Bituminous Coal of jurassic age is found in places from the Hokanui Hills to Catlin's River, and the same formation extends under a considerable part of the plains between the Hokanuis and the sea, but it is here covered up by a thick deposit of gravel and silt. This includes an area of more than 1000 square miles, but over the whole of it no seam thick enough to pay for working on a large scale has as yet been found. Such may, however, exist, but as each year goes by without finding it, the probability of its existence rapidly diminishes, especially as no good seam has been found in this formation in any part of New Zealand.

Up a small creek flowing into the Otapiri, three thin seams have been discovered, none of them however exceeding six inches in thickness. Higher up there exists, according to Mr. J. R. Thomson, a seam of carbonaceous shale about four feet thick, but without any good coal in it. West of the Makarewa, coal has been found in several localities, but here also it does not exceed a foot in thickness. Coal has also been found at the Seaward Downs; and at the Toi-tois, near the mouth of the Mataura, Mr. Brunton, C.E., has been at considerable expense in exploring some outcrops of coal

by drives and a shaft. Unfortunately his success has not, as yet, been very great, the coal seams being spoilt by numerous shale partings. The following is the section here as I made it out in January, 1872 :—

	feet.
Conglomerate } Green sandstone }	200 +
Fire elay, about	6
Coal with shale partings	1½
Dark grey shale	40
Coal (7 thin seams with shale)	6
Green sandstone, about	20
Conglomerate	15 +

Coal has also been found at Waikawa, and in the neighbourhood of Catlin's River, but always in thin seams.

The following analyses have been made by Dr Heetor and Mr. W. Skey, of coals from this district :—

—	Catlin's River.	Seaward Downs, 2 analyses.	Waikawa, average of 4 seams.	Average of the whole.
Water	4.20	8.93	8.95	8.23
Fixed Carbon	59.40	55.50	44.43	49.73
Hydro-Carbon	35.00	31.34	37.28	35.27
Ash	1.40	4.22	12.07	8.31

These analyses shew that, even if a thiek seam with less ash were found, still the eoal would probably be very inferior to that of Newcastle (N.S.W.). At present we eannot inelude this district among our eoal fields.

Mount Hamilton.—Bituminous eoal of upper eretaceous age but of good quality is also found at Mount Hamilton, but unfor tunately the thinness of the seams, and the small extent of the for mation put the praetibility of working it quite out of the question It is situated near the summit of Mount Hamilton, at an elevation of 2,500 feet above the plain of the Oreti. (See Fig 4.) The coal formation is composed of yellow sandstone with thin seams of coal,

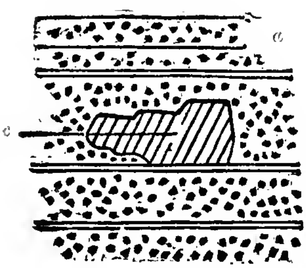


Fig. 22.—Boulder in sandstone: *a*, sandstone; *b*, coal; Waipara formation: *c*, sandstone boulder.

underlaid by shales with several seams of good black coal, the uppermost and thickest of which is only ten inches in thickness. The upper sandstone is fine grained, but in it I noticed a large angular boulder of dark gray sandstone —(fig. 22)—measuring eight feet by 3 feet in the exposed face, no other pebbles of any kind were near it, and it rested on the top of a thin coal seam. I presume that there can be no doubt but that this boulder has been floated to its present position among the roots of a tree, and that therefore the coal beds are formed partly from drift wood.*

The following is the mean of two analyses of this coal made by Mr. W. Skey :—

Water	1·63
Fixed Carbon...	49·04
Hydro-Carbon	38·02
Ash	9·80

A small seam of bituminous coal has also been found on Coal Island, Preservation Inlet, and I shall mention it again when noticing that coal field.

Coal Fields.

The coal fields in a new country are generally soon found, and this is especially the case in New Zealand where the seams, lying usually among hills, crop out to the surface, and are easily recognised. The first published notice of coal in Otago was by the the Hon. W. Mantell, who mentioned in 1850, the occurrence of coal at Matakea Point (Shag Point). In 1855 Dr. C. Forbes of H.M.S. Acheron, described the coals at Saddle Hill and Preservation Inlet. The Wairaki coal field was known to the settlers in 1850, and during the same year the mine at Coal Point was opened in the Clutha field; while the Green Island and Tokomairiro fields were opened in 1861. So that all our coal fields were known 13 years ago; consequently we cannot expect any important additions to them, except possibly in the Te Anau district, between the Lake and the Mararoa River, and also west of the Lower Waiau River, and in both these cases the coal, if it exists at all, will be found under the tertiary rocks near their junction with the slates. It is also, of course, possible that a thick seam may be found in the

*Dr. Hector reported on this coal to the Provincial Government of Otago in January, 1872, and said that it belonged to the same formation as that of Otapiri and Waikawa. (Provincial Government *Gazette*, January 17, 1872.)

Hokanuis or Waikawa district, but this could hardly be considered as a new coal field, as coal has been known in these localities for a long time although no workable seam has been yet discovered. It is not possible to give any approximate estimate of the total quantity of coal in the Province until topographical maps on a scale of six inches to a mile, have been prepared of all the coal fields, and the geology filled in on them in detail. This would be a very long and expensive process, and the results obtained would be entirely for the benefits of future generations, for we already known of sufficient coal to last for many years, as well as the most accessible places for working it.

Shag Point Coal Field.—The coal at Shag Point was already known, and used in 1848, but the mine was, I believe, first opened by Mr. Hutchinson, in February, 1863. This coal formation extends inland from the north head of Shag River for about four miles to where the north road crosses the Horse Range. To the northwards it stretches as far as the south branch of the Otepopo river, a distance of twelve miles, and a small outlier occurs across the north branch of the Otepopo; the whole area occupied is about 26 square miles. The only previously published account of this field is by Dr. von Haast, who examined it in the autumn of 1871, and his report was published in the "Reports of the Geological explorations during 1871-2" (Geological Survey of New Zealand).

On its western margin this formation forms hills more than 1000 feet high cut by deep ravines, but towards the east the hills are much lower; the whole country, however, occupied by it is much broken. On the south the beds are considerably disturbed, and sometimes inclined at high angles, but towards the north they get more horizontal, and pass under the tertiary clays of Moeraki and Hampden. The lower part of the formation consists chiefly of conglomerates passing upwards into sandstones, which on the south are interstratified with beds of conglomerate that thin out northward. Coal has hitherto only been found in the southern and more disturbed part of the district, but I know of no reason why it should not also extend further north.

Along the north bank of the Shag River, at least six workable seams can be seen, varying in thickness from 3 to 7 feet, and at the coal mine, near Vulcan Point, there are two seams, the upper one being 7 to 10 feet, and the lower 4 feet in thickness, and separated by 4 feet of shale. It is the upper of these seams that is at present being worked. Both these seams are probably identical with some of those previously mentioned, so that at present we cannot feel sure that more than six workable seams exist, the total thickness of which is probably about 25 feet. It will, therefore, be seen that a considerable quantity of coal exists in this field, but as we do not know how far the seams extend north, we cannot say how much. Dr.

von Haast estimates that in the 70 acres surrounding Shag Point, there are "about 1,600,000 tons of coal, which, in order to allow for possible disturbances or other causes by which this quantity of coal might be diminished, reduced by more than one third, would still leave us at least 1,000,000 tons of workable coal." I quite agree with Dr. Haast that this is a moderate estimate.

This coal is the best of our brown coals. It contains little or no resin, but rounded pebbles of white quartz are sometimes found embedded in the middle of it, a peculiarity found also in the coals at Pakawau, near Nelson, and at Green Island.

The following is the average of three analyses made by Dr. Hector :—

Water	16.57
Fixed Carbon ...	43.15
Hydro-Carbon ...	34.03
Ash	6.58

The formation may perhaps, also underlie the tertiary rocks at Bushy Park, south of the Shag River. But this is uncertain, for the conglomerates interstratified with the coal and shale at Shag Point, prove that the coast line composed of palæozoic rocks, along which the formation was deposited, extended much further south than at present, and may have occupied the whole of the country south of the Shag River. But be this at it may, it is certain that if the Shag Point coal series underlies Bushy Park, it must be at a considerable depth; for as has been pointed out (p. 89), a large river occupied the Shag Valley in lower eocene times, when the land stood much higher than now, and this river must have excavated a deep valley through the coal series, which was afterwards filled up by tertiary rocks, as shown in Section VIII., which is an ideal representation of what probably exists under the mouth of the Shag River. Consequently I am of opinion that any attempt to find this coal south of Shag River, would not at present prove remunerative, even if it were successful.

Green Island and Saddle Hill Coal Field.—This coal field occupies the valley of the Kaikorai stream, near Dunedin. On the west it is bounded by the mica schist ridge that runs from the Chain Hills, south of Saddle Hill, to the mouth of the Otokaia. On the north it is overlaid, and probably cut off by the volcanic rocks of Flagstaff Hill, and on the east it is cut off by the basalts of Dunedin and Forbury. It has a length of about five miles with a breadth of two, and a superficial area of about 9 square miles.

The coal at Saddle Hill was mentioned by Dr. Forbes in 1855, and a mine was opened at Fairfield in 1861. It was worked by a drive from a gully. The field, and the nature of the coal in it have been described by Dr. Lauder Lindsay in his lecture delivered in Dunedin in 1862, and afterwards in a paper on the tertiary coals of New Zealand, which was published in the

"Transactions of the Royal Society of Edinburgh for 1865. Dr. Hector reported on it in his departmental report of the Geological Survey of Otago in 1864; in his first general report on the coal deposits of New Zealand in 1866; and in the reports of the Geological Explorations for 1871-2.

On the western margin of the field the lower beds of the formation crop out to the surface, and dip gently E.S.E., but towards Caversham they become quite horizontal, consequently it is only on the western margin that the coal seams, all of which belong to the lower part of the series, come near the surface. In the centre of the valley the formation has undergone considerable denudation, and the coal series is here overlaid by clays, grits, and ferruginous conglomerates belonging to the newer pliocene or pleistocene periods. These upper beds also contain small seams of lignite with wood almost unaltered, which have nothing to do with the coal of the older formation. This denudation however was not deep enough to affect any of the coal seams. (Sec. IX.)

Besides smaller seams two good ones, varying from six feet to fourteen feet in thickness, are known, and we may perhaps take eighteen feet as the average thickness of the known workable seams. At present coal has been found only in the south west part of the field, but there is no reason to doubt that it extends to Flagstaff Hill on the north, and to Dunedin and Forbury on the east, although at the eastern boundary it will be at a considerable, but not unworkable depth. This would give about 155,000,000 of tons in the field, which after deducting the usual one-third, leaves more than 100,000,000 of tons available. This is the only field in New Zealand where the coal is worked by shafts. The following is the average of five analyses made by Dr. Hector of coals from this field:—

	Aver.	Max.	Min.
Water	18·86	21·01	14·22
Fixed Carbon ...	40·85	43·12	38·24
Hydro-Carbon ...	36·57	41·04	34·06
Ash	3·92	5·78	2·25

These analyses show that the coal, although very free from ash, is inferior in quality to other brown coals, and it has more the appearance of a lignite than a brown coal.

Clutha and Tokomariro Coal Field.—This field is situated on the sea coast from the Clutha to a little beyond the Tokomairiro River, and is distant from Dunedin between 40 and 60 miles. On the west it is bounded by the alluvial flats of the Clutha and Kaitangata Lake, and on the north by the northern base of Mount Misery, and the slate ranges between the Toko-

mairiro and Akatore Rivers. In shape it forms a broad triangle with a base along the sea coast of about 15 miles, and a height from the sea to the Tokomairiro Plains of eight miles, thus having an area of about 60 square miles. It forms a series of round backed hills, with deep valleys between, and attains its greatest elevation (1098 feet) at the summit of Mount Misery. Another small patch of the same formation lies on the north-west side of the Tokomairiro plain, between the Woolshed Creek and the Tokomairiro River, but it is not yet known to contain any coal.

The first coal mine in Otago was opened in this field at Coal Point in 1859, by Mr. J. G. Lewis, but it has since been abandoned, owing probably to finding coal in a more accessible position at Kaitangata. The coal field at Tokomairiro was opened in 1861. The only report on this field is that by Dr. Hector in his departmental report of the Geological Survey of Otago in 1864, which he afterwards reproduced with some additions in the reports of Geological Explorations in 1871-2.

In the southern part of the field, from Kaitangata to Wangaloa, the beds are considerably disturbed, and occasionally faulted, but in the northern portion, from Mount Misery down both banks of the Tokomairiro River on the edge of the basin, they dip slightly to the south, and then gradually become horizontal. (Sec. VII.)

At Kaitangata the only seam that was being worked at the time of my visit, was between 3 and 4 feet thick, and dipped 20° S.W., but since then I understand that a much thicker seam has been found better placed for working economically. Along the sea coast between the Clutha and Wangaloa, the low sea cliffs, some 15 to 25 feet in height, show several seams of coal varying from 5 to 20 feet in thickness. The sequence of the rocks here is not very clear, and the coal appears to vary a good deal in thickness, but it is evident that at least three seams with an average total thickness of 30 feet exist in this part of the field. From Wangaloa to the mouth of the Tokomairiro River no coal is seen, as the coal-bearing formatiou is covered up by newer rocks, but several seams are known to exist in the gullies more inland. South west of Mount Misery, and facing the Tokomairiro Plain, a fine seam belonging to Messrs. Finch and White, is seen dipping 15° S.S.W. This seam is composed as follows :—

Coal	6	feet
Coaly Shale	2	„
Coal...	18	„
Total	26	„

which gives a total thickness of 24 feet of coal. On the left side of the Tokomairiro River two or three seams at least are known to exist, varying from 6 to 20 feet in thickness. Apparently the

main seam is 6 to 10 feet thick on the margin of the basin, and swells out to over 20 feet towards the sea, but until all the drives and borings made in this part of the field are connected together by an accurate survey, it is impossible to feel certain whether these are all the same seam or not. The coals in this field are often covered by conglomerates or gravels, and I noticed that the upper edge of the coal seams are sometimes much eroded, and that fragments of the coal are found in the overlying conglomerate (Fig. 23); from which it would appear that the coal had become hard before it was eroded. Alluvial gold is found in these conglomerates. It thus appears that although coal is found abundantly from one end of this field to the other, the seams vary considerably in thickness, and it would not perhaps be advisable to take more than 20 feet as their average total thickness over the whole field. This would give 1,152,000,000 of tons contained in the field; and if we make the usual deduction of one third for barren ground, waste, &c., it will leave 768,000,000 tons of available coal. This is the largest coal field in New Zealand.

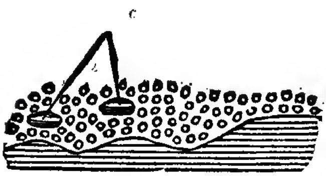


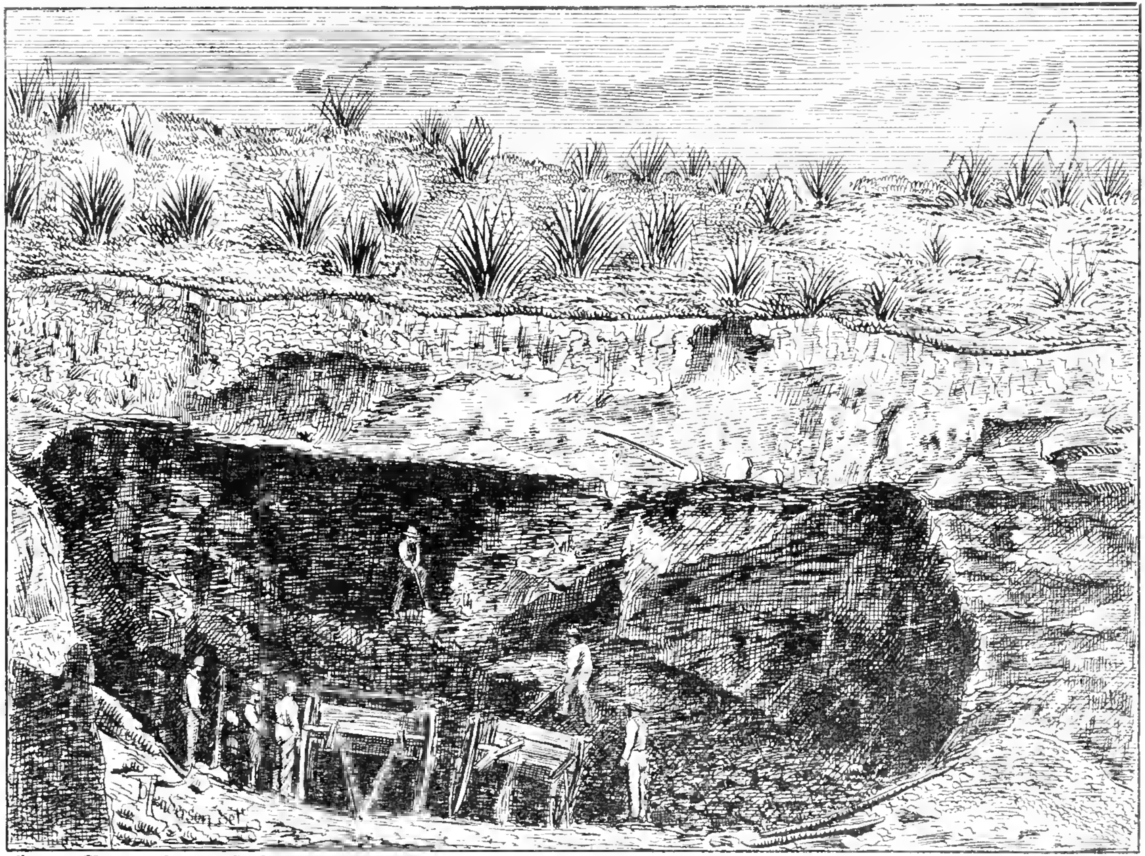
Fig. 23.—Denuded coal, Tokomairiro. *a*, Loose conglomerate, and *b*, coal, Oamaru formation; *c*, fragments of coal in conglomerate.

The following table shows the composition of these coals. It is compiled from analyses made by Dr. Hector and Mr. W. Skey:—

—	Tokomairiro. (2 analyses.)	Kaitangata. (2 analyses.)	Coal Point. (2 analyses.)	Whole Field. (14 analyses.)		
				Aver.	Max.	Min.
Water	11·70	14·09	15·86	14·93	20·91	7·27
Fixed Carbon ...	43·93	41·62	42·26	42·56	48·70	36·57
Hydro-Carbon ...	37·55	35·28	35·63	35·93	40·17	29·61
Ash	5·91	9·01	6·25	6·04	12·30	3·30

It will be thus seen that these coals very nearly equal that from Shag Point in the amount of fixed carbon that they contain while the amount of water in them is slightly less.

Wairaki Coal Field.—This coal field is about 45 miles distant from Invercargill. The formation here skirts along the southern bases of the Takitimu Mountains, and Wairaki Downs; from Taylor's Creek on the west, as far as the alluvial plain of the Jacob River on the east, a distance of about 18 miles. Near the Jacob



From a Photo by Burton Bros.

REAL MACKAY COAL MINE, TOKOMAIRIRO.

River it has a breadth of about three miles which gradually diminishes westward, thus forming a narrow triangle, the apex of which is at Taylor's Creek, and the base at the southern spur of Mount Beaumont, called the Night-Cap. This will give an area of about 27 square miles. Another outlier is stated to lie at the base of Mount Twinlaw, but I did not visit it, and the coal may also probably extend under Sharp Ridge and Grassy Creek, towards the Waiau.

This formation never rises to great altitudes, but forms low rounded hills.

This field was reported on by Dr. Hector, in 1869,* and by myself, in 1872†

The whole field appears to be considerably disturbed, but the beds have generally a S.W. dip ; if, however, the formation is continued under Grassy Creek and Sharp Ridge, the beds may be expected to become flatter.

At Taylor's Creek, a section is opened on the edge of the basin, and a seam of coal five feet thick is seen to rest on the edges of slates and sandstones (Fig. 24). The coal is here covered with shales and micaceous sandstone, the whole dipping 20°S.W. Following down the creek more black shales are seen to overlie the micaceous sandstone, which probably indicate the presence of a second seam of coal, but the section stops suddenly. As the section here is evidently quite on the edge of the basin, the seam of coal may very likely get thicher in a south-westerly direction.

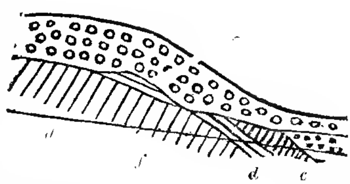


Fig. 24.—Coal at Taylor's Creek, Southland. Oamaru formation—*a*, gravel ; *b*, micaceous sandstones ; *c*, shaley coal ; *d*, chocolate shales ; *e*, blue shale ; *f*, slates (Kaikoura formation).

At Linton home station, two distinct seams can be made out, but the thickness of neither is known. The lower seam is overlaid by micaceous sandstone like that at Taylor's Creek, and the upper one is in the sandstone. This latter has a very uneven floor. The dip here is 25° S.S.W.

In the lower part of the Morely Creek, the following section can be seen :—

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* Progress report of the Geological Survey of New Zealand, 1869, pages iv. and v.

† Reports of Geological Explorations, 1871-2 (Geological Survey of New Zealand) p. 93.

Yellow sandstone	... ...	20 +
Blue marlstone (leaves and *Unio*)		20
Brown coal	... ...	3
Shale ...	... ...	1
Brown coal	... ...	2
Shale (with leaves)	... ...	12
Brown coal	... ...	2
Shale (with leaves)	... ...	10 +
		70 +

The whole dipping 25° W. b. S.

Higher up the same creek the coal is found in several places covered by the same micaceous sandstone as at Taylor's Creek and Linton, the thickness is 10 feet, and the dip 25° S.W.; and at the west side of the Night-Cap the thickness is 11 feet, and the dip, according to Mr. J. R. Thomson, is 11° E.S.E.;* and at Opio Creek, it is 3 feet thick, with a dip of 15° E, also according to Mr. Thomson.

A tolerably approximate estimate of the quantity of coal in this field cannot at present be given, but it certainly contains 100,000,000 tons.

Near the Morely Creek station, the coal was on fire for about a year in 1858-9, and about ten acres of it have been burnt out.

The following is the average of three analyses of these coals by Mr. W. Skey and Dr. Hector:—

Water	... ...	15.12
Fixed-Carbon	.. ...	47.16
Hydro-Carbon	... ...	32.99
Ash	... ...	5.06

From which it would appear to be a very superior brown coal.

Orepuki Coal Field.—The Orepuki coal field is much smaller than the others. It occupies a part of the valley of the Waimeamea, which rises in the Longwood Range, and runs into the sea south of the Waiau. It forms a triangle about 3 miles in breadth and one in height, and has consequently an area of about 1½ square miles. The coal seam is only exposed in water-races, some of which have fallen in, and in no place was I able to measure its thickness. It is, however, evident that this is considerable, and, according to the miners, it is from ten to fifteen feet. The coal is situated at about a height of 150 or 200 feet above the sea, and about five miles from the beach. It is covered by dark, very tough shales, and the floor is composed of chocolate coloured shales. The upper part of the formation is soft, green sandstone, and the dip is 10° S.S.W.

* Mr. Thomson gives two apparent dips as 1¼ inches to a foot to the south, and 2½ inches to a foot to the east; from which it would result that the true dip is 11° E.S.E., and not to the N.N.E. as stated by Dr. Hector. (Appendix to the Journal of the House of Representatives, 1873, vol. II., E. 10. p. 37.)

Near the beach the coal formation has been washed away, and a thick deposit of sands and gravels of pleistocene age has been deposited in its place. These pleistocene beds also contain seams of lignite, which are exposed in the sea cliff, and which have nothing to do with the brown coal formation. This coal field is about 20 or 25 miles from Riverton. The following is an analysis of the coal made by Dr. Hector :—

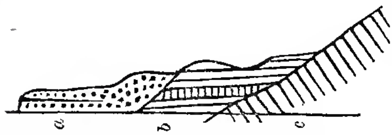
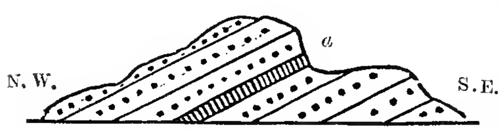


Fig. 25.—Coal at Orepuke: *a*, soft sandstone and clay with lignite (Pleistocene); *b*, coal formation (Oamaru formation); *c*, slates (Kaikoura formation).

Watcr	19.10
Fined Carbon	41.10
Hydro-Carbon	37.20
Ash	2.60

Preservation Inlet Coal Field.—The formation in which this coa field is situated occurs quite at the south west corner of Otago. Owing to its inaccessible position, it has not yet been properly explored, but as well as I could judge from the steamer, appears to commence at the Green Islets, and to extend continuously to Preservation Inlet. It occurs also at Coal Island; at the point between Preservation and Chalky Inlets, and on Chalky Island, forming a strip of low hill, thickly covered by bush, about 13 miles in length by four in breadth at Preservation Inlet, and tapering to a point at Green Islets. Omitting all north west of Preservation Inlet, the area thus mentioned would be about 26 square miles. It is, however, only on the east side of Preservation Inlet that a workable coal seam has been found at present. Here two good seams, each about three feet in thickness, are found between Otago's Retreat and Puysegur Point. The first of these is just round the point opposite the south end of Coal Island; a road has been made to it from Otago's Retreat, and the seam has been opened by a small drive. The seam here dips 25° W. (Fig. 26.) The coal is a good brown coal, like that of the Clutha field, and contains a considerable quantity of resin. Above this are several other quite small seams. The other workable coal seam crops out on the shore about half-way between the last and Puysegur Point, and dips about 15° W.



Otago's Retreat.

Fig. 26.—Coal at Preservation Inlet: *a*, coal seam.

I was not able to examine personally the coal strata on Coal Island, but no workable seam has been found there. Dr. Hector reports that on Coal Island the only seam of coal he found dipped 15° E. in one place, and to the west a few hundred yards off. It was only four to nine inches thick, but the coal was of good quality, quite equal to the Sydney coal that he had on board. He also discovered another small seam, six to fourteen inches in thickness, at Price's Beach, a small bay lying north east of Gulche's Head; but the quality of coal in this seam was inferior to that on Coal Island. It would be useless to try to estimate the quantity of coal in this field until more is known about it.

This coal field was first mentioned in 1855 by Dr. C. Forbes, of H.M.S. Acheron; afterwards by Dr. Hector in 1863, and again in 1873; also by Mr. A. Johnstone in 1862. A company was formed in Dunedin to work it, and Captain Greig, late Harbour Master at the Bluff, went there to make a report. It was this party that formed the road from Otago's Retreat to the first workable seam, and made a drive 99 feet in length into it. He informs me that the seam commenced with a thickness of two feet, increased to three feet three inches, and then decreased again to two feet four inches. He excavated 45 tons from this drive. This company has now abandoned the ground.

The following analyses by Dr. Hector and Mr. W. Skey will show the composition of both qualities of coal in this field:—

—	Coal Island. (3 analyses.)	Three Foot Seam. (3 analyses.)
Water	8·70	16·52
Fixed Carbon	60·47	45·66
Hydro-Carbon	25·68	31·49
Ash	6·19	4·53

Bituminous Shale.

Bituminous shale is found near the head of the Waitati Stream behind Dunedin. The first distinct outcrop of the shale is in the bed of the stream about half a mile above the point where the Blueskin track crosses it. The shale here *(b)* is about six feet in thickness, and is underlaid by a thin bed of what appears to be a very good fire clay; below this is a clayey sandstone with peculiar white

markings about two feet thick, and below this comes a considerable thickness of the Caversham sandstone (*c*). The beds here dip 18° S.W. About 20 chains up the valley another outcrop of the shale is seen, forming a precipitous cliff on the side of the valley (*b″*). The shale in this place is about 18 feet in thickness, and is underlaid by the same beds as are below it lower down the valley, and is covered by basaltic rocks (*a*). I could not make out the dip with accuracy, but it seems to be slightly to the east. This portion of the strata appears to have been thrown up by a fault that crosses the valley in a N.W. and S.E. direction. (See Fig. 27.)

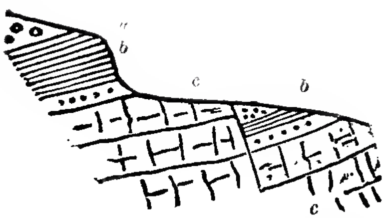


Fig. 27.—Bituminous shale, Waitati. *a*, basalt; *b*, *b″*, bituminous shale; *c*, Caversham sandstone.

The fact that the shale thickens from 6 to 18 feet in a distance of 20 chains, makes it appear likely that this great thickness may not be retained for any considerable distance, but the country is so thickly covered with bush that it will be difficult to trace the outcrop. But, however this may be, an abundant supply of material is evidently available, and it is most advantageously situated for extraction.

Professor Black informs me that this shale contains 42 gallons of crude oil per ton.

Another bituminous shale, equal in quality to that of Waitati, is found at Orepuki, and others have been reported from Mount Hamilton, Otapiri Creek, and Wyndham River. No doubt abundant supplies of these shales will be found in the Putataka formation.

Roofing Slate.

Very good slate has been discovered in the Otepopo district, on a branch of the Kauroo River. These slates belong to the Kakanui formation, and it is probable that they may also occur at other places situated in the area occupied by this formation (see map); but I doubt if they are likely to be found in a more accessible place than the present discovery.

These slates split very freely, but the cleavage is not true slaty cleavage, for it evidently follows the the plane of the bedding. On the other hand it is not ordinary lamination. It appears to me to be a spurious cleavage induced along the original plane of bedding by vertical pressure when the slates were undergoing a slight metamorphism. But although these slates are not equal to the best Welsh slates for purposes that require a ground or polished surface, they will, I think, be found nearly equal to them for roofing. Their

hardness is quite sufficient, and that they will stand the weather perfectly is proved by the excellent state of preservation of surfaces long exposed to the weather. I saw large blocks, looking as sharp and fresh as if they had been just detatched from the rock, which were almost buried in the vegetation that had grown up around them; while at the same time the very small amount of vegetation (confined to lichens) growing on the exposed surfaces shew that they do not readily absorb moisture. They will also stand well a hole being knocked through them with a slater's hammer, not a single one splitting that was tried. The waste in working a slate quarry is generally supposed to be five tons to one of marketable slate, and it is therefore very important for the economical working of a quarry that it should be so situated that this large waste can be got rid of without much expense. This can be easily secured in the present locality.

Flag Stones.

In a letter of Dr. Hector to the Superintendent* he mentions that Mr. Howell had informed him that extensive beds of good flagstones are found in accessible positions at Preservation Inlet. I do not know what localities were meant, and the subject never appears to have been mentioned again by Dr. Hector. Inferior stones for paving could be got cheaply from the gneiss in most of the Sounds, but they would not be equal to proper flagstones. However I believe that gneiss, mica schist, and hornblende schist are all extensively used for pavements in the United States.

Building Stones.

As the building stones of Otago have been so ably described by Mr. W. Blair, C.E.,† it will be unnecessary for me to do more than make a very few remarks on the subject.

Sandstones.—These are almost entirely confined to the Putataka and Waipara formations; the older rocks being too much jointed, and the newer ones seldom being hard enough for use. However there are a few exceptions among the ferruginous grits of the Oamaru formation, and the white hard sandstones (sarsen stones) of the lacrustine beds in the interior. Sandstones of good quality are found in the Horse Range in the Hokanui Hills, and between the Mataura and Catlin's River, but although valuable locally, they are not likely to come into general use.

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*Provincial Government *Gazette,* June 17, 1863.

† On the building materials of Otago. Part I., building stones. Read before the Otago Institute, July 13, 1875, and published in the newspapers.

Limestones.—The most important building stone in the Province is undoubtedly the Oamaru limestone. Its beautiful color, and ease of working, combined with its hardening on exposure, make it a most valuable building material. The absorbent nature of this stone naturally throws a doubt on its capability of resisting the action of the atmosphere of a town; but hitherto the oldest buildings of it in Dunedin have not suffered in the least from this cause, except by loss of color. This stone is exactly similar to the limestone of Malta, of which the town of Valetta is built. Many of the buildings of that town are of very great age, and show no sign of deterioration, although those portions of the fortifications that are exposed to the spray of the sea are very much decomposed.

Bluestones.—This is the name applied in the Colony to all kinds of volcanic rocks used in building. These are generally either trachyte breccia, or basalt. The former, which when good is decidedly superior to basalt both in color and durability, is only found in the neighborhood of Dunedin Harbour. Very excellent quarries are opened both at Port Chalmers and Dunedin, and it is used largely in Dunedin for all the more substantial buildings. Basalt is found in many parts of the Province as well as near Dunedin, and will in time no doubt be more extensively used than at present.

Granite, &c.—Large quantities of granite are found in Preservation and Chalky Inlets, but it is very coarse grained, and probably, therefore, liable to decomposition, and except for inside pillars, for which purpose its color is well suited, I do not think that it would be a safe stone to trust to. The whole of the other West Coast Sounds seem remarkably bare of good building stone in sufficient quantities for use; but the syenite of the Bluff Hill is of excellent quality, and far superior to anything on the West Coast. It is also more accessible for working. Good syenite will no doubt also be found at Stewart Island, but I do not know of a locality for it, all the eruptive rocks that I have seen from there being very coarse grained.

Materials capable of being Polished.

A very pretty grey marble, streaked with white, is found in abundance at Blue Mountain in the Horse Range, where it is burnt for lime. Although very much jointed at the surface, it may improve as the quarry is developed, and I think that blocks of sufficient size to make chimney pieces, pillars, &c., could be obtained.

There is also a black limestone, with shells, somewhere near Tokomairiro, that would make a very handsome black marble. I do not know the exact locality of this limestone, and have only seen hand specimens of it.

The so-called "statuary marble"* from the West Coast, although beautifully white, is of a totally different texture from true statuary marble, having internally a coarsely crystalline texture, which would cause it to split under the chisel, and would of course quite unfit it for statuary purposes.

Lime.

Limestones fit for burning into lime are found in many places near the sea board of Otago, and also at Lake Wakatipu; all, except the marble of Horse Range, belonging to the Oamaru formation.

In the interior also stalactites and stalagmitic incrustations are found in the caves in the mica schist rocks, and near Clyde a travertine, that has been deposited by a small stream running from the schists, is burnt for lime.

Several analyses of these limestones will be found in the "New Zealand Exhibition Jurors Reports and Awards, App. A, p. 448." But it is not necessary for me to reproduce them here, especially as I have not been able to identify the localities of many of them.

The great increase in the use of concrete for building has made the manufacture of Portland cement a very important industry, which it would be highly advantageous to introduce if possible into the Province. Portland cement is said to be manufactured from pure carbonate of lime (chalk) ground under water, with the mud from rivers running through a limestone district. If this latter is necessary, it appears to me that of all the rivers in the Province, those near Oamaru are most likely to furnish the best material, and probably the neighborhood of Kakanui mouth, would be found a suitable place for establishing this industry.

The Hampden boulders (septaria) would, no doubt, also furnish an inferior cement, but I think that the supply of the material would be found very limited.

Materials for Pottery, Glass, &c.

Very good clays for making pottery are known from several places in the Province, and they will probably be found in all the old lake basins. A deposit of kaolin, formed from decomposing granite dykes has been discovered in Stewart Island, but I do not know its exact locality, nor its extent. Kaolin is also stated by Dr. Hector to occur at Manuherikia Plains, Arrow River, &c.†

I have seen very good specimens of potash felspar from Stewart Island, where it is said to occur in veins in sufficient quantity for use. Mr. W. F. Kinnear has shown me water-worn specimens of

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* Jurors Reports and Awards, p. 294, and App. A, p. 391.

† Jurors' Reports and Awards, p. 267.

excellent red flint, from Tapanui, but I do not know in what quantity it occurs, nor from what formation it is derived. Flint can, however, be obtained from Amuri Bluff, in the Province of Nelson.

Quartz sand is of course common, but probably the best material would be obtained from crushing the quartz gravels of the gold washings. Oxide of lead, soda, oxide of manganese, and saltpetre, would have to be imported, but the manganese can be obtained at the Bay of Islands.

The establishment of glass works in Dunedin is an undertaking that could hardly fail to be remunerative, and is one that would be of great benefit to the whole Province. The saving effected by using up all the old glass would by itself be an important consideration.

Good fire clays are found in most of the coal fields; they are always much improved by long exposure to the weather.

Grinding and Polishing Materials.

Good sharp sandstone, or gritstone, suitable for grindstones, is found in the Horse Range, while whetstones, and scythe stones could probably be supplied from some of the more arenaceous mica schists, as at Mount Alta. Hone slate and Lydian stone are not uncommon in the Kakanui and Kaikoura formations; and polishing power (diatomaceous earth) is found in Strath Taieri, and probably also in some of the other old lake basins.

Gold.

Gold mining in the Province is the subject of a separate report by Mr. Ulrich, and I shall therefore confine myself to making a few remarks on those points that belong more to a geological than to a mining report.

It has been already pointed out that we have in the sandstone of the Shag River (ante, p. 47), in the conglomerates over the coal at Wangaloa (ante, p. 48), and probably also in the Blue Spur (ante, p. 93), evidence of gold drifts having been formed in the eocene period; consequently the age of any of our gravel beds will not affect its auriferous character, the oldest being quite as likely to contain gold as the newest.

It has also been pointed out that during the later oscillations of the land the rivers have filled up their beds during subsidence, and that some of them have excavated fresh ones during the subsequent elevation. Consequently, if deep leads are defined as auriferous gravels formed in old river beds which have afterwards been filled up, many must certainly exist in Otago, and in the case of the Shotover, Lammerlaw Creek, &c., these deep leads have already been found. But owing to the mountainous character of Otago, and to the fact that the principal river valleys were in existence long before the oldest gravels and cements now remaining were

formed, the deep leads of Otago are very different in character from these of Victoria. Our deep leads are confined to the neighbourhood of the present rivers and streams, and must be always more or less parallel to them, as both the old river channel and the present one are but different cuts in the same great valley. Owing also to the last elevation of the land having been longer continued than the one preceding it, the rivers now run at lower levels than they did in their old channels, and therefore most of our deep leads will be at higher elevations than the surface workings in the neighbouring streams. This is, of course, very advantageous in working them.

The terrace formation, which was formed by the rivers during subsidence of the land, is intermediate in age between the old gutters and the drifts at present forming, and the workings in it are also intermediate between deep leads and shallow workings, but I do not know that they call for any special remarks.

The previous observations apply only to those deposits that have been formed by rivers, and not to the old lake basins, the chances of finding deep leads in which must be discussed separately.

If we suppose a valley through which a river was running to have its slope gradually reversed by unequal elevation or subsidence of the land, it is evident that the velocity of the river would gradually diminish until the water was stationary, and a lake was formed, and that this lake would then gradually increase in depth. The streams on the sides and at the head of the lake would form deposits of gravel, probably auriferous, at their mouths, while the finer material, freed from gold, would form a bed of clay on the bottom, covering up the old river gravel. The gravel deposits at the mouths of streams continuing to increase at each flood, would constantly advance further into the lake and cover up the clay, (Fig. 28.), until ultimately the lake would be filled up, and the river would once more run uninterruptedly through the valley, but on the top of the lacustine beds.

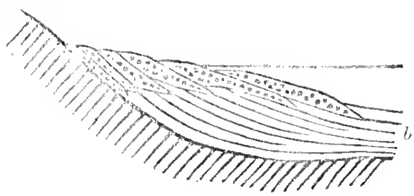

Fig. 28. – Section through River fan forming in a Lake: *a*, Gravels and sand; *b*, clay.

The extent to which these gravels would be advanced towards the centre of the lake would depend upon the relative proportions of gravel and finer material poured into it. If the amount of fine material was small, the gravel deposits on either side might advance across the lake until they met one another. If, on the contrary, the fine material was in excess, the lake might be filled up by clay before the gravels had advanced far from the margin.

If on the other hand the lake, instead of having been formed by unequal movements of the land, had been scooped out by a glacier, the hollow left when the glacier melted away would be at once filled by still water forming a lake. The filling up process would then commence as in the last case, but as no river had ever run along the bottom of the lake there would be no river gravel for the clay to cover up, only the angular unsorted fragments of rock that might have dropped off the glacier as it melted away. But this would not be the only difference, for the glacier formed lake would for a long time after its formation be fed by streams flowing from glaciers, which bring down a far larger proportion of fine mud than ordinary streams. Consequently in a glacier formed lake not only would there be no deep lead along the bottom, but the lateral gravels would have less chance of pushing far into the lake than in the other supposed case.

I have already given—(ante p. 87)—the reasons that have convinced me that the old lake basins in this Province have been formed by glaciers, consequently I am of opinion that no deep leads exist along the bottom of them, and that the auriferous gravels are confined to those parts of the margin of the old lakes immediately adjoining the mouths of the streams that ran into them. It must, however, be remembered that in many cases these streams did not fall into the lake at right angles to it, but often very obliquely, and the gravels, therefore, would be carried in the direction of the streams and not straight across the lake.

We must also remember that during the course of the gravels down the river the gold gets separated from its matrix, and falls to the bottom, where it gets collected together, but it is very gradually pushed down the stream during floods by the violent movement of the gravel over it. But when these gravels and gold get pushed into the lake, they get scattered over the fan shaped deposit forming at the mouth of the stream—some being pushed one way and some another, and being now in still water there is no further movement to bring the gold together. Consequently the gold in these deposits is not collected in such definite leads as in the beds of rivers, and it is seldom that these deposits would be rich enough to pay except by hydraulic sluicing; consequently all these deposits when situated below the surface drainage of the country are useless.

The difference between these ideas on the distribution of gold, and those of Dr. Hector, published in the Otago Provincial Government *Gazette*, for September 3rd, 1862, are due partly to Dr. Hector considering the old lakes to have been caused principally by the subsidence of the mountains, which, he says, "appear to have sunk more rapidly where most lofty and massive,"* and partly to his thinking that rivers play a very minor part in liberating gold from its matrix. He says, "bearing in mind the now well established fact that after

* Progress report of Geological Survey, 1868-9, p. vi.

the original wearing down of the rocky matrix, the mechanical liberation of its contained gold has been effected for the most part by long continued wave and current action, either in the sea or large inland lakes, and that the comparatively feeble and limited action of streams has merely exerted an ever-recurring sifting and sorting influence on the materials thus prepared, we can at once perceive that in this rock-bound basin the conditions have been most favourable for retaining and assorting the *debris* formed by the degregation of the surrounding schists during the submergence of the lands in tertiary times."

These views are of course quite different from mine, and I think different also from those of most geologists, but as Dr. Hector has re-asserted the correctness of his opinion,† and stated that it has "now been well established by the results of the workings on the different gold fields," I think it desirable to reproduce it here in order that the reader may have both views before him to choose from.

It has been already said that the gold in the Province has been chiefly derived from the schist rocks, and the only important exception to this is at Orepuki. Here the country consists of slates and sandstones pierced by dykes of eruptive rocks. Exactly the same geological conditions extend to Stewart Island, and to Preservation Inlet, and it is quite possible that a gold field may exist west of Waiau, in the neighbourhood of Howloko and Monowai Lakes.

But it must be remembered that in the schist rocks the conditions are similar over large districts, and the gold is more or less universally distributed and easily found. But in the slate rocks the favourable conditions are local, and the gold consequently will be local also. This is probably the reason why gold has not been found in the north part of Stewart Island, for the geological conditions appear to be very favourable.

Iron Ores.

Hæmatite, of excellent quality, containing 94 to 96 p.c. of oxide of iron, is found near Maori Point on the Shotover, where it is said to occur in a lode six feet thick. As good limestone is found at Lake Wakatipu, and brown coal at Gibbstown, about 18 miles distant, it is possible that in time iron works may be established here with advantage.

Hæmatite is also found in the vicinity of Port Molyneux, and coal could easily be obtained; but lime would have to be brought from Waihola by rail, or from Dunedin by sea.

Very good clay iron ore exists near Tokomairiro, and as limestone and coal are both found in the immediate neighbourhood, and a railway runs through the district, the conditions are very favourable for an iron foundry, provided the ore can be obtained in sufficient quantity.

† Progress report of Geological Survey, 1868-9, p. vi.

From Maruawhenua, I have also received excellent samples of clay iron stone, and here also limestone and coal are sufficiently near.

Titaniferous iron sand is found in considerable quantity at Port William in Stewart Island; but limestone would have to be brought from Winton, and coal from Kaitangata or the Wairaki field.

Brown coal is used in Germany and Austria for the manufacture of iron with the application of step grates, such as are described in Mr. Ulrich's report.

Copper Ores.

The copper lode at Moke Creek, Lake Wakatipu, was discovered in about the year 1863, and up to the present time is the only one of any importance known in the Province. Mr. Hacket in his report, describes it as a true lode, 1½ feet thick, striking with the country rocks, but dipping at an angle of only 15°, while the strata dip at 50°. Another lode near Waipori was discovered about two years later.

Copper, when it exists in quantity, is of all metals the most easily found, for it generally covers the neighbouring rocks with large green stains. And as the Province has been extensively prospected for the last 10 years without any further discoveries, it is improbable that other lodes exist, except perhaps in some of the West Coast Sounds.

Antimony Ores.

Stibnite is found in considerable quantity at the Arrow River, Carrick Ranges, Waipori, and other places. At present antimony ore is exported from Borneo to England and America, where it is principally used in forming the alloy for type metal.

Tungstate of Lime.

This mineral occurs rather plentifully in the Wakatipu, Shotover, and Arrow districts, where from its weight and color it is called "white Maori" by the miners. It is possible that it may have considerable economic importance, and that it might pay to collect and export it, but I am not aware whether its value has yet been tested in the London market.

Alum.

Alum shales are found at Waikouaiti, but it is uncertain whether they would pay to work. It will also probably occur in most of the brown coal fields, but as it could be manufactured much more cheaply in some of the volcanic districts in the North Island, it would hardly be advisable to try it here.

Retinite.

This fossil resin occurs in such abundance in some of the lignites, that it would probably pay to collect it for the manufacture of varnish.

Water Supply.

The water supply of towns by artesian wells is the only geological question that need be discussed under this head, and Invercargill and Riverton are the only towns where the conditions appear to be favourable for obtaining water by this means. These towns are built on a series of gravels, silts, and clays, which rise in altitude from the sea, until they skirt round the bases of the Hokanui and Moonlight Ranges. These gravels rest upon a tolerably level platform of sandstones similar to those in the Hokanuis, and as these rocks appear near the surface in the Seaward Downs, it is probable that they are present at no very great depth under Invercargill. Rain water from the inland mountains probably percolates through the lower beds of the gravel series, and finds its way slowly into the sea; and if a bed of clay underlies Invercargill, and extends far enough inland to rise to a higher level than the town, the conditions will be favorable for obtaining water by artesian wells. For if this clay were pierced by a bore-hole, the underlying water would rise up through it in preference to forcing its way out to sea. Whether this assumed bed of clay exists or not it is of course impossible to say, but the chances are in favour of it, and it is well worth a trial.

APPENDIX A.

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MAPS WITHOUT REPORT.

Hector, J.—Geological map of New Zealand, 1869.

MANUSCRIPT MAP AND SECTIONS, BY DR. HECTOR, PRESERVED IN THE OTAGO MUSEUM.

Geological Map of Otago, 1864.

Sections, all made in 1862—

- *Coast between the Clutha and Coal Point.
- Oamaru Cape.
- Otepopo River, seven miles from the mouth.
- Junction of Moeraki, series with schists on the Otepopo river.
- *Chain Hills to the sea.
- *Taieri Plain to the mouth of Kaikorai Stream.
- Chain Hills to Flagstaff Hill.
- Coal strata on Mataura River.
- Tertiary strata of Upper Pomahaka, and enlarged diagram of the same.
- Right bank of the Manuherikia River.
- Right side of the Clutha at Moa Flat.
- Lower Manuherikia Valley.
- Tokomairiro to Lammerlaw Ranges.
- Portion of the same near Lawrence enlarged.

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* These have been since published by Dr. Hector, to illustrate his report on the Clutha and Green Island coal fields. (Geol. Expl., 1871-2, p. 165.)

APPENDIX B.

List of the Minerals of Otago.

O.M. means that the mineral is represented in the Otago Museum by specimens from the Province.

Carbon and its Compounds.

1. Graphite—Few's Creek, Dunstan; West Coast (Hector) ... ... O.M.
2. Retinite—Common in lignite; Caversham, in sandstone ... ... O.M.

Haloid Minerals.

3. Glauber Salt—Mount Nicholas Cave, Lake Wakatipu O.M.
4. Gypsum—Moeraki; Awamoko ... ... O.M.
5. Calcite—Abundant ... ... O.M.
6. Aragonite—Dunedin, in basalt ... ... O.M.
7. Epsomite—Murison's Station (Hector) ... ... —
8. Alum—Tokomairiro, Waikouaiti, &c. ... ... —
9. Wavellite—Stewart Island (Hector, Cat. Col. Mus. p. 126). ... ... —

[illegible]

10. Quartz—Abundant ... ... O.M.
11. Chalcedony—Otepopo, Moeraki, [illegible] ... O.M.
12. Jasper—Moeraki (Plasma of Hector), Clutha, &c. ... O.M.
13. Chert—Moeraki, &c. ... ... O.M.
14. Hyalite—Dunedin, in Phonolite... . O.M.
15. Talc—West Coast, in quartz (Hector) ... ... —
16. Steatite—Milford Sound (Hector) ... ... —
17. Chlorite—Queenstown, &c., in schist ... ... O.M.
18. Serpentine—Windley Creek ... ... O.M.
19. Marmolite—Anita Bay ... . O.M.
20. Nephrite—Anita Bay ... ... O.M.
21. Schiller Spar—West Coast (Hector) ... ... —
22. Augite—In basalt, &c., abundant ... ... O.M.
23. Diallage—In Gabbro, McKerrow Lake ... ... O.M.
24. Hypersthene—West Coast (Hector) ... ... —
25. Bronzite—West Coast (Hector) ... ... —
26. Hornblende—Abundant ... ... O.M.
27. Tremolite—Milford Sound (Hector) ... ... —
28. Asbestos—Milford Sound (Hector) ... ... —
29. Olivine—Dunedin, &c., in basalt; Milford Sound (Hector) ... ... O.M.
30. Halloysite—Basalt, near Dunedin ... ... O.M.

31. Stilbite	Basalts, near Dunedin	O.M.
32. Natrolite	Basalts, near Dunedin	O.M.
33. Chabazite	Basalts, near Dunedin (Hector)	—
34. Gmelinite	Basalts, near Dunedin (Hector) ...	—
35. Prehnite	Basalts, near Dunedin (Hector)	—
36. Orthoclase—Stewart Island, West Coast		O.M.
37. Albite—West Coast (Hector); in schist, at Roaring Meg (Hector)		—
38. Labradorite—In basalt, Dunedin, &c.		O.M.
39. Epidote—West Coast (Hector)		—
40. Garnet—Resolution Island, Bligh Sound, Milford Sound		O.M.
41. Tourmaline—West Coast (Hector)		—
42. Muscovite—Abundant		O.M.
43. Biotite—West Coast, common		O.M.
44. Lepidolite—In marble, Thompson's Sound ...		O.M.
45. Margarite	In schists and gneiss (Hector) ...	—
46. Lepidomelane	In schists and gneiss (Hector) ...	—
47. Topaz—Chatto Creek, Arrow (Hector); Waipori (Hector)		—
48. Zircon—Timbrell's Gully (Hector)		—

METALS AND METALLIC ORES.

49. Brookite—In trap at Otepopo (Hector)	—
50. Scheelite—Head of Lake Wakatipu, Shotover, Arrow, Bendigo	O.M.
51. Stibnite—Waipori, Carrick Ranges, Arrow, &c. ...	O.M.
52. Iron pyrites—Common; large crystals at Maori Point, Shotover	O.M.
53. Marcasite—In coal, &c.	O.M.
54. Mispickel—In alluvial deposits, &c.; Milford Sound (Hector)	O.M.
55. Magnetite—Dunstan, Maori Point	O.M.
56. Hæmatite—Dunstan, Dunedin (Hector)	O.M.
57. Specular Iron—Stewart Island, Longwood Range ...	O.M.
58. Clay Ironstone—Tokomairiro, Maerewhenua, &c. ...	O.M.
59. Limonite, Lansdown, Port Molyneux	O.M.
60. Ilmenite—In black sands	O.M.
61. Chromic Iron—Milford Sound	O.M.
62. Glauconite—In green sandstones; in schists (Hector)	O.M.
63. Siderite—In cavities, in schist (Hector)	—
64. Sphærosiderite—In basalts, Dunedin	O.M.
65. Vivianite—Black's, as crystals in Moa bones (Hector)	O.M.
66. Rhodonite—Dunstan	O.M.
67. Manganite—Dunstan (Hector)	—
68. Erythrine—Schists and gneiss on West Coast (Hector)	—
69. Zinc Blende—Bendigo, Rough Ridge (Ulrich) ...	—

70. Galena—Tokomairiro, Rough Ridge, Bendigo ... O.M.
71. Native Mercury—Tokomairiro ... ... O.M.
72. Cinnabar—Waipori, Dunstan, and Serpentine (Hector) .. .. O.M.
73. Native Copper—Moke Creek, Waitahuna, Dunstan, and Kawarau (Hector) ... ... O.M.
74. Chalcopyrite—Moke Creek ... ... O.M.
75. Erubesite—Dunstan ... ... O.M.
76. Bournonite—Rough Ridge ... ... —
77. Malachite—Moke Creek, Waitaki, and Pomahaka (Hector) ... ... —
78. Chrysocolla—Moke Creek, Milford, and Bligh Sounds (Hector) ... ... —
79. Platinum—Steward Island ... ... O.M.
80. Gold—Widely distributed ... ... O.M.
81. Silver—Head of Lake Wakatipu, Skippers, Kawarau Gorge ... ... O.M.

APPENDIX C.

Fauna of Otago.

The following list contains those vertebrata and mollusca that I know from personal observation, or from specimens sent to the Museum, to live in Otago.* There are in addition several species of shells in the Museum that have not yet been determined. For many of the corrections in the names of the shells, I am indebted to a paper called "Remarks on certain shells in F. W. Hutton's catalogue of the Marine Mollusca of New Zealand," by E. von Martens, which is not yet published, but which the Hon. W. Mantell has kindly allow me to read. O.M. after a name means that the species is represented in the Otago Museum; and in the list of mollusca, C.M.M., stands for the "Catalogue of the Marine Mollusca of New Zealand."

MAMMALIA.

Chiroptera.

1. *Mystacina velutina*, Hutton. *M. tuberculata* Gray, not *S. tuberculatus* Forster ... ... O.M
2. *Scotophilus tuberculatus*, Forster (Vespertilo) ... O.M

Pinnipedia.

3. *Stenorhynchus leptonyx*, Blainville (Phoca)... ... O.M.
4. *Arctocephalus hookeri*, Gray. *Gypsophoca subtropicalis*, Gray. Trans. N.Z. Inst. VI., p. 88 ... O.M.
5. *Arctocephalus cinerus*, Peron (Otaria) ... ... O.M.

Cetacea.

6. *Neobalæna marginata*, Gray. Stewart Island ... O.M.
7. *Capera antipodarum*, Gray. *Eubalæna australis*, Hector (in part), not of Gray .. .. O.M.
8. *Macleayius australiensis*, Gray ... ... O.M.
9. *Sibbaldius antarcticus*, Burmeister (?) .. ... O.M.
10. *Balænoptera h*[illegible], Gray ... ... O.M.
11. *Catodon macrocephalus*, L. ... ... O.M.
12. *Tursio metis*, Gray. *Clymenia novæ-zealandia*, Hector, in part ... ... O.M.
13. *Electra clancula*, Gray ... ... O.M.
    This is not *D. superciliosus* Lesson (Voy Coquille. Mammiferes, Pl. 9, fig. 2) as supposed by Dr. Gray (Trans. N.Z. Inst. VI., p. 89)
14. *Orca gladiator* var *australis*, Gervais. *O pacifica*, Hector, not of Gray... ... ... O.M.

* Three of the fishes, however, are introduced on the authority of Dr. Hector.

15. *Beluga kingii*, Gray (?). *Globiocephalus macrorhynchus*, Hector. Trans. N.Z. Inst., VII. p. 261 ... ... O.M.
16. *Berardius arnuxi*, Duvernoy ... ... —
17. *Mesoplodon hectori*, Gray (Berardius). *M. knoxi*, Hector ... ... O.M.

AVES.

Accipitres.

1. *Harpa novæ-zealandiæ*, Latham. *H. brunnea* Gould, *F. ferox*, Peale ... ... O.M.
2. *Circus approximans*, Peale ... ... O.M.
3. *Sceloglaux albifacies*, Gray. Very rare. ... ... O.M.
4. *Spiloglaux novæ-zealandiæ*, Gmelin ... ... O.M.

Psittaci.

5. *Cyanorhamphus novæ-zealandiæ*, Sparrmann. *P. forsteri*, Finsch ... ... O.M.
6. *Cyanorhamphus auriceps*, Vigors... ... ... O.M.
7. ,, *alpinus*, Buller ... ... O.M.
8. *Nestor meridionalis*, Gmelin. *N. superbus*, *N. montanus*, and *N. occidentalis*, Buller. ... ... O.M.
9. *Nestor notabilis*, Gould ... ... O.M.
10. *Stringops habroptilus*, Gray. *S. greyi*, Gray ... O.M

Picariæ.

11. *Halcyon vagans*, Lesson ... ... O.M.
12. *Eudynamis taitiensis*, Sparrmann ... ... O.M.
13. *Chrysococcyx lucidus*, Gmelin ... ... O.M.

Passeres.

14. *Hirundo nigricans*, Vieillot. An occasional straggler O.M.
15. *Graucalus parvirostris*, Gould. *Colluricincla concinna*, Hutton ... ... —
16. *Rhipidura flabellifera*, Gmelin ... ... O.M.
17. ,, *fuliginosa*, Sparmann. *R. tristis*, Homb and Jacq ... ... O.M.
18. *Clitonyx ochrocephala*, Gmelin ... ... O.M.
19. *Phyllodytes novæ-zealandiæ*, Gmelin. *C. maculicaudus*, Gray ... ... O.M.
20. *Prosthemadera novæ-zealandiæ*, Gmelin ... ... O.M.
21. *Anthornis melanura*, Sparrmann. *A. ruficeps*, Pelz. Abundant ... ... O.M.
22. *Zosterops lateralis*, Latham ... ... O.M.
23. *Gerygone flaviventris*, Gray. *G. assimilis*, Buller. *G. aucklandica*, Pelz
24. *Myiomoira macrocephala*, Gmelin. *Petroica, dieffenbachü*, Gray ... ... O.M.
25. *Myioscopus albifrons*, Gmelin ... ... O.M.

26. *Xenicus longipes*, Gmelin. Rare ... ... O.M.
27. ,, *gilviventris*, Pelzeln. *X. haasti*, Buller. Very rare ... ... —
28. *Acanthisitta chloris*, Sparrman ... ... O.M..
29. *Sphenœacus punctatus*, Quoy and Gaimard. *S. fulvus*, Gray. Rare ... ... O.M.
30. *Anthus novæ zealandiæ*, Gmelin. *A. grayi*, Bonaparte O.M.
31. *Keropia crassirostris*, Gmelin ... ... O.M.
32. *Creadion carunculatus*, Gmelin. *C. cinereus*, Buller ... O.M.
33. *Glaucopis cinerea*, Gmelin ... ... O.M.

Columbæ.

34. *Carpophaga novæ-zealandiæ*, Gmelin. *C. spadicea leucophæa*, Homb and Jac ... ... O.M.

Gallinæ.

35. *Coturnix novæ-zealandiæ*, Quoy and Gaimard. Very rare O.M.

Grallæ.

36. *Ocydromus australis*, Sparrman ... ... O.M.
37. ,, ,, var *troglodytes*, Gmelin ... O.M.
38. ,, ,, var *hectori*, Hutton ... ... O.M.
39. ,, *fuscus*, Du Bus. *O. nigricans*, Buller. *O. brachypterus*, Buller ... ... O.M.
40. *Ocydromus fuscus*, var *finschi*, Hutton ... ... O.M.
41. *Eulabeornis philippensis*, *L. Rallus pectoralis Less.* Rare ... ... O.M.
42. *Ortygometra affinis*, Gray. Rare. ... ... O.M.
43. ,, *tabuensis*, Gmelin. Rare ... ... O.M.
44. *Porphyrio melanotus*, Temminck ... ... O.M.
45. *Notornis mantelli*, Owen. Very rare, perhaps extinct —
46. *Limosa novæ-zealandiæ*, Gray ... ... O.M.
47. *Himantopus leucocephalus*, Gould ... ... O.M.
48. ,, *novæ-zealaniæ*, Gould. *H. melas*, Homb and Jacq ... ... O.M.
49. *Tringa canutus*, Linnæus. Rare ... ... O.M.
50. *Gallinago aucklandica*, Gray. *G. pusilla*, Buller ... O.M.
51. *Charadrius obscurus*, Gmelin ... ... O.M.
52. ,, *bicinctus*, Jardine ... ... O.M.
53. *Thinornis novæ-zealandiæ*, Gmelin. Rare ... ... O.M.
54. *Anarhynchus frontalis*, Quoy and Gaimard. Rare ... O.M.
55. *Ardea egretta*, Gmelin. *A. alba*, Ellman, not of Lin. *A. syrmatophora*, Buller ... ... O.M.
56. *Ardea novæ hollandiæ*, Latham. Rare ... ... O.M.
57. ,, *sacra*, Gmelin. Rare ... ... O.M.
58. ,, *pusilla*, Vieillot. *Ardeola novæ-zealandiæ*, Purdie. Very rare ... ... O M.
59. *Botaurus poiciloptilus*, Wagler ... ... O.M.

Anseres.

60.	*Dendrocygna eytoni*, Gould. A single flock only, probably all killed	O.M.
61.	*Casarca variegata*, Gmelin. *A. cheneros*, Forster ...	O.M.
62.	*Anas superciliosa*, Gmelin. *A. leucophrys*, Forster ...	O.M.
63.	„ *chlorotis*, Gray	O.M.
64.	*Querquedula gibberifrons*, Mull. *A. gracilis*, Buller. Rare	O.M.
65.	*Spatula rhynchotis*, Latham. *S. variegata*, Gray ...	O.M.
66.	*Fulix novæ-zealandiæ*, Gmelin. *A. atricilla*, Forster	O.M.
67.	*Hymenolaimus malacorhynchos*, Gmelin	O.M.
68.	*Lestris catarractes*, Linnæus. *L. antarctica*, Lesson ...	O.M.
69.	*Larus dominicanus*, Lichtenstein. *L. vociferus*, Bruch	O.M.
70.	„ *novæ-hollandiæ*, Stephens. *L. scopulinus*, Forster. *L. jamesoni*, Wilson.	O.M.
71.	*Larus pomare*, Bruch. *L. bulleri*, Hutton. *L. melanorhynchus*, Buller	—
72.	*Sterna caspia*, Pallas	O.M.
73.	„ *frontalis*, Gray. *S. albifrons*, Peale ...	O.M.
74.	„ *nereis*, Gould. Rare	—
75.	*Hydrochelidon antarctica*, Forster. *H. albistriata*, Gray	O.M.
76.	*Diomedea exulans*, Linnæus. *D. spadicea*, Gmelin ...	O.M.
77.	„ *melanophrys*, Boie	O.M.
78.	„ *chlororhyncha*, Gmelin	O.M.
79.	„ *culminata*, Gould	O.M.
80.	*Phœbetria fuliginosa*, Gmelin. *D. antarctica*, Banks	O.M.
81.	*Ossifraga gigantea*, Gmelin. *P. brasiliana*, Latham	O.M.
82.	*Halodroma urinatrix*, Gmelin. *P. tridactyla*, Forster	—
83.	*Puffinus griseus*, Gmelin. *P. tristis*, Forster ...	O.M.
84.	„ *gavia*, Forster. Rare	—
85.	*Procellaria cinerea*, Gmelin. *P. hæsitata*, Forster	O.M.
86.	„ *capensis*, Linnæus. *P. nævia*, Brisson	O.M.
87.	„ *gouldi*, Hutton	O.M.
88.	„ *cærulea*, Gmelin. *P. similis*, Forster...	O.M.
89.	*Prion turtur*, Smith. *P. velox*, Banks	O.M.
90.	„ *vittatus*, Gmelin. *P. latirostris*, Bonn ...	O.M.
91.	*Thalassidroma fregata*, Linnæus. *P. marina*, Latham	O.M.
92.	*Dysporus serrator*, Banks. Rare	—
93.	*Graculus carbo*, Linnæus. *Phalacrocorax novæ hollandiæ*, Stephens	O.M.
94.	*Graculus glaucus*, Hombron and Jacquimot. *G. chalconotus*, Gray	O.M.
95.	*Graculus varius*, Gmelin	—
96.	„ *carunculatus*, Gmelin...	O.M.
97.	„ *punctatus*, Gmelin	O.M.

98. *Graculus melanoleucus*, Vieillot ... ... O.M.
99. „ *brevirostris*, Gould ... ... O.M.
100. *Eudyptes antipodes*, Hombron and Jacquimot ... O.M.
101. „ *pachyrhynchus*, Gray ... ... O.M.
102. „ *catarractes*, Gmelin ... ... O.M.
103. „ *vittatus*, Finsch ... ... O.M.
104. „ *atratus*, Hutton. The Snares ... ... O.M.
105. *Eudyptula minor*, Forster. *E. undina*, Gould ... O.M.
106. *Podiceps cristatus*, Linnæus. *P. hectori*, Buller ... O.M.
107. „ *rufipectus*, Gray ... ... O.M.

Struthiones.

108. *Apteryx australis*, Shaw ... ... O.M.
109. „ *oweni*, Gould ... ... O.M.

REPTILIA.

Lacertilia.

1. *Mocoa zealandica*, Gray ... ... O.M.
2. „ „ var *variegata*, Buller ... ... O.M.
3. „ *grandis*, Gray. *M. laxa*, Hutton ... ... O.M.
4. *Naultinus punctatus*, Gray. *N. elegans*, Gray ... O.M.
5. „ „ var *lineatus*, Gray ... ... O.M.
6. „ *pacificus*, Gray. *N. granulatus*, Gray ... O.M.

PISCES.

Plagiostomata.

1. *Callorhynchus antarcticus*, Lacepede ... ... O.M.
2. *Galeus canis*, Linnæus ... ... O.M.
3. *Mustelus antarcticus*, Gunther ... ... O.M.
4. *Lamna glauca*, Muller and Henle ... ... O.M.
5. *Alopecias vulpes*, Gmelin ... ... O.M.
6. *Scyllium laticeps*, Dumeril. Dusky Bay only ... O.M.
7. *Acanthias vulgaris*, Risso ... ... O.M.
8. *Raja nasuta*, Solander ... ... O.M.
9. *Trygon brevicaudata*, Hutton ... ... O.M.

Acanthopterygii.

10. *Oligorus prognathus*, Forster. (Perca.) *O. gigas*, Owen ... ... O.M.
11. *Arripis salar*, Richardson. Rare. ... ... O.M.
12. *Therapon (?) rubiginosus*, Hutton ... ... O.M.
13. *Scorpis hectori*, Hutton. Dusky Bay ... ... —
14. *Haplodactylus meandratus*, Solander. *H. donaldi*, Haast ... ... O.M.
15. *Pagrus unicolor*, Quoy and Gaimard. Very rare ... O.M.
16. *Chilodactylus macropterus*, Forster .. ... O.M.
17. *Mendosoma lineata*, Gray. (West Coast Sounds, Hector.) ... ... —

18. *Latris hecateia*, Richardson ... ... O.M.
19. " *ciliaris*, Forster ... ... O.M.
20. *Sebastes percoides*, Solander ... ... O.M.
21. *Scorpæna cruenta*, Solander. West Coast Sounds ... O.M.
22. *Agriopus leucopœcilus*, Richardson. Common ... O.M.
23. *Trachichthys trailli*, Hutton ... ... O.M.
24. *Lepidopus caudatus*, Euphrasen ... ... O.M.
25. *Thyrsites atun*, Euphrasen ... ... O.M.
26. *Trachurus trachurus*, Lin. (West Coast Sounds, Hector) ... ... —
27 *Seriola lalandii*, Cuvier and Valenciennes... ... O.M.
28· *Seriolella porosa*, Guichen ... ... O.M.
29· *Gasterochisma melampus*, Richardson ... ... —
30·. *Neptomenus brama*, Gunther ... ... O.M.
31. *Kathetostoma monopterygium*, Bleeker ... ... O.M.
32. *Leptoscopus huttoni*, Haast ... ... O.M.
33. *Crapatalus angusticeps*, Hutton. (Leptoscopus) ... O.M.
34. *Perciscolias*, Forster ... ... O.M.
35. *Cheimarrichthys forsteri*, Haast ... ... O.M.
36. *Bovichthys variegatus*, Richardson... ... ... O.M.
37. *Notothenia maoriensis*, Haast ... ... O.M.
38. " *cornucola*, Richardson ... ... O.M.
39. " *angustata*, Hutton ... ... O.M.
40. " *microlepidota*, Hutton ... ... O.M.
41. *Trigla kumu*, Lesson and Garnot. Rare ... ... O.M.
42. *Eleotris gobioides*, Cuvier and Valenciennes ... ... O.M.
43. *Trypterygium nigripenne*, Cuvier and Valenciennes ... O.M.
44. " *medium*, Gunther ... ... O.M.
45. *Auchenopterus compressus*, Hutton (Trypterygium) .. O.M.
46. *Acanthoclinus littoreus*, Forster ... ... O.M.
47. *Trachypterus altivelis*, Kner ... ... O.M.
48. *Agonostoma forsteri*, Bleeker ... ... O.M.
49. *Hemerocœtes acanthorhynchus*, Forster ... ... O.M.
50. *Psychrolutes latus*, Hutton ... ... O.M.
51. *Centriscus humerosus*, Richardson ... . O.M.
52. *Diplocrepis puniceus*, Richardson ... ... O.M.
53. *Trachelochismus pinnulatus*, Forster ... ... O.M

Acanthopterygii-pharyngognathi.

54. *Labrichthys fucicola*, Richardson ... ... O.M.
55. " *celidota*, Forster ... ... O.M.
56. " *bothryocosmus*, Richardson ... ... O.M.
57. " *psittacula*, Richardson. Dusky Bay only... O.M.
58. *Odax vittatus*, Solander ... ... O.M.
59. *Coridodax pullus*, Forster ... ... O.M.

Acanthini.

60. *Merluccias gayi*, Guichen. *Gadus australis*, Hutton. Rare ... ... O.M.

61. *Lotella bacchus*, Foster. Abundant ... ... O.M.
62. *Genypterus blacodes*, Forster. Abundant ... ... O.M.

Pleuronectoidæ.

63. *Pseudorhombus scaphus*, Foster (W.C. Sounds, Hector) ...
64. *Ammotretis rostratus*, Gunther ... ... O.M.
65. *Rhombosolea monopus*, Gunther ... ... O.M.
66. " *flesoides*, Gunther. *R. leporina*, Hutton, not of Gunther ... ... O.M.
67. *Rhombosolea tapirina*, Gunther ... ... O.M.
68. " *retiaria*, Hutton ... ... O.M.
69. *Peltorhamphus novæ-zealandiæ*, Gunther ... ... O.M.

Physostomi.

69. *Hemirhamphus intermedius*, Cantor ... ... O.M.
71. *Prototroctes oxyrhynchus*, Gunther. *Retropinna upokororo*, Hector ... ... O.M.
72. *Gonostoma australis*, Hector (Maurolicus) ... O.M.
73. *Retropinna richardsoni*, Gill. *R. osmeroides*, Hector O.M.
74. *Galaxias fasciatus*, Gray ... ... O.M.
75. " *olidus*, Gunther (?) ... . O.M.
76. " *brevipennis*, Gunther. *G. grandis*, Haast O.M.
77. " *attenuatus*, Jenyns ... ... O.M.
78. *Gonorhynchus greyi*, Richardson ... . O.M.
79. *Clupea sprattus*, var *antipodam*, Hector ... ... O.M.
80. *Anguilla aucklandii*, Richardson ... ... O.M.
81. " *australis*, Richardson ... ... O.M.
82. *Conger vulgaris*, Cuvier ... ... O.M.
83. *Leptocephalus altus*, Richardson ... ... O.M.

Lophobranchii.

84. *Doryichthys elevatus*, Hutton ... ... O.M.
85. *Stigmatophora longirostris*, Hutton ... ... O.M.
86. *Hippocampus abdominalis*, Lesson ... ... O.M.

Plectognathi.

87. *Monocanthus convexirostris*, Gunther ... ... O.M.
88. *Tetrodon richei*, Fréminville ... . O.M.
89. *Orthagoriscus mola*, Linnæus ... ... O.M.

Cyclostomata.

90. *Geotria australis*, Gray ... ... —
91. " *chilensis*, Gray ... ... O.M.
92. *Bdellostoma cirrhatum*, Forster ... ... O.M.

MOLLUSCA.

Cephalopoda.

1. *Octopus cordiformis*, Quoy and Gaim (Pinnoctopus) O.M.
2. *Argonauta tuberculata*, Shaw; *A. nodosa*, Solander MSS. Broken specimens are occasionally found at Stewart Island ... ... O.M.

3. *Ommastrephes sloanii*, Gray ... ... O.M.

Heteropoda.

4. *Ianthina exigua*, Lamark. Rare. ... ... O.M.
5. *Trophon ambiguus*, Homb and Jacq. *Murex lyratus*, C.M.M., nec Lam ... ... O.M.
6. *Trophon stangeri*, Gray (Fusus) ... ... O.M.
7. „ *inferus*, Hutton (Fusus). Rare ... ... O.M.
8. *Neptunea plebeius*, Hutton (Fusus) ... ... O.M.
9. *Euthria lineatus*, Martyn (Fusus). *F. linea et lineatus*, C.M.M. ... ... O.M.
10. *Drillia trailli*, Hutton (Pleurotoma) ... ... O.M.
11. „ *lævis*, Hutton (Pleurotoma) .. ... O.M.
12. „ (?) *albula*, Hutton (Pleurotoma) ... .. —
13. *Lachesis sulcata*, Hutton ... ... O.M.
14. *Defranchia luteo-fasciata*, Reeve; *Daphnella letourneuxiana*, Hutton. C.M.M. not of Crosse ... O.M.
15. *Tritonium spengleri*, Chemnitz ... ... O.M.
16. *Ranella vexillum*, Sowerby. Common in Foveaux Straits ... ... O.M.
17. *Cominella nassoides*, Reeve (Buccinum), *B. zealandicum*, C.M.M., not of Reeve ... ... O.M.
18. *Cominella funereum*, Gould (Buccinum), *B. costatum*, C.M.M., not of Quoy ... ... O.M.
19. *Purpura haustrum*, Martyn ... ... O.M.
20. *Polytropa striata*, Martyn; *Purpura succincta*, C.M.M. not of Martyn ... ... O.M.
21. *Polytropa rugosa*, Quoy and Gaimard ... ... O.M.
22. „ *quoyi*, Reeve; *P. scobina*, C.M.M. ... O.M.
23. „ *tristis*, Dunker; *P. quoyi*, C.M.M. ... O.M.
24. *Ancillaria australis*, Quoy and Gaimard. West Coast Sounds ... ... O.M.
25. *Voluta pacifica*, Lam ... ... O.M.
26. ,, „ var γ *V. elongata*, Swainson ... O.M.
27. *Lamellaria ophione*, Gray; *L. indica*, C.M.M., not of Leach ... ... O.M.
28. *Natica zealandica*, Quoy and Gaimard. Rare. ... O.M.
29. „ *vitrea*, Hutton ... ... O.M.
30. *Acus caliginosa*, Reeve (Terebra); *Cerithium kirki*, Hutton ... ... O.M.
31. *Obeliscus roseus*, Hutton ... ... —
32. *Chemnitzia zealandica*, Hutton ... ... O.M.
33. *Odostomia lactea*, Angas ... ... O.M..
34. *Struthiolaria gigas*, Sowerby. Rare ... ... —
35. „ *nodulosa*, Lamark. Not common ... O.M.
36. „ *australis*, Gmelin. *S. vermis*, Martyn. **Rare** ... ... O.M.
37. *Cancellaria trailli*, Hutton ... ... O.M.

38.	*Trichotropis flavida*, Hinds. *T. inornata*, Hutton ...	O.M.
39.	*Cerithium subcarina*, Sowerby	O.M.
40.	„ *terebelloides*, Martens. *C. cinctum*, Hutton	O.M.
41.	„ *exilis*, Hutton	O.M.
42.	*Inferus angasi*, Crosse. *C. minimus*, Hutton ...	—
43.	*Littorina cincta*, Quoy and Gaimard	O.M.
44.	„ *diemenensis*, Quoy and Gaimard. Not common	O.M.
45.	*Rissella (?) varius*, Hutton. (Adeorbis)	O.M.
46.	*Rissoa rugulosa*, Hutton	O.M.
47.	„ *nana*, Hutton	O.M.
48.	„ *subfusca*, Hutton	O.M.
49.	„ *plicata*, Hutton	O.M.
50.	„ *purpurea*, Hutton	O.M.
51.	„ *impolita*, Hutton	—
52.	„ *rosea*, Hutton	O.M.
53.	*Turritella rosea*, Quoy and Gaimard	O.M.
54.	„ *pagoda*, Reeve. Not common	O.M.
55.	„ *symetrica*, Hutton	O.M.
56.	*Calyptræa maculata*, Quoy and Gaimard	O.M.
57.	*Trochita tenuis*, Gray	O.M.
58.	*Crypta unguiformis*, Lamark	O.M.
59.	*Turbo smaragdus*, Lamark	O.M.
60.	„ „ var *β*., Hutton	O.M.
61.	„ *rubicundus*, Reeve	O.M.
62.	*Imperator cookii*, Lamark. Rare	O.M.
63.	„ *imperialis*, Lamark. Common in Foveaux Straits	O.M.
64.	*Rotella zealandica*, Homb and Jacq. Otago Heads ...	O.M.
65.	*Polydonta tiarata*, Quoy and Gaimard. Rare ...	O.M.
66.	*Diloma æthiops*, Gmelin. *T. zealandicus*, Quoy and Gaimard	O.M.
67.	*Diloma hectori*, Hutton. (Labio)	O.M.
68.	„ *gaimardi*, Philippi. *T. cingulatus*, Quoy and Gaimard	O.M.
69.	*Diloma nigerrima*, Linnæus	O.M.
70.	*Trochocochlea subrostrata*, Gray. (Labio, C.M.M.) ..	O.M.
71.	„ *sanguinea*, Gray. (Gibbula, C.M.M.) ...	O.M.
72.	*Zizyphinus tigris*, Martyn	O.M.
73.	„ *punctulatus*, Martyn. *Turbo granosus* C.M.M., not of Lam.	O.M
74.	*Cantharidus iris*, Chemnitz. Not common ...	O.M.
75.	*Gibbula nitida*, Adams. Abundant	O.M.
76.	„ *inconspicua*, Hutton. (Chrysostoma) ...	O.M.
77.	*Margarita rosea*. Hutton. (Chrysostoma) ..	O.M.
78.	*Haliotis iris*, Lamark	O.M.
79.	„ *rugoso-plicata*, Chemnitz. *H. australis*, Lam	O.M.

80.	*Haliotis gibba* Philippi, *H. virginea*, C.M.M. not of Lam.	O.M.
81.	*Lucapina monilifera*, Hutton. Rare	—
82.	*Emarginula striatula*, Quoy and Gaim (?)... ...	O.M.
83.	*Tugalia parmophoroides*, Quoy and Gaim. *T. elegans*, Gray	O.M.
84.	*Parmophorus unguis*, L. *P australis*. Lam. Common	O.M.
85.	*Tectura pileopsis*, Quoy and Gaim	O.M.
86.	„ *fragilis*, Quoy and Gaim...	O.M.
87.	*Patella inconspicua*, Gray	O.M.
88.	„ *margaritaria*, Chemnitz	O.M.
89.	„ *imbricata*, Reeve	O.M.
90.	„ *redimiculum*, Reeve. *P. pottsi*, Hutton ...	O.M.
91.	„ *decora*, Philippi. *N. radians*, in part C.M.M.	O.M.
92.	„ *affinis*, Reeve. *N. radians*, in part C.M.M....	O.M.
93.	„ *cantharus*, Reeve	O.M.
94.	*Chiton canaliculatus*, Quoy and Gaim	O.M.
95.	„ *pellis-serpentis*, Quoy and Gaim	O.M.
96.	„ *quoyi*, Deshayes	O.M.
97.	„ *longicymbus*, De Blainville	O.M.
98.	*Tonicia undulata*, Quoy and Gaimard	O.M.
99.	„ *rubiginosa*, Hutton	O.M.
100.	*Acanthopleura cœlatus*, Reeve	—
101.	*Acanthochætes porphyreticus*, Reeve	O.M.
102.	*Katherina violacea*, Quoy and Gaim	O.M.
103.	*Cryptoconchus monticularis*, Quoy and Gaim ...	O.M.
104.	*Aplysia brunnea*, Hutton	O.M.
105.	*Onchidella nigricans*, Quoy and Gaim	O.M.
106.	*Siphonaria obliquata*, Sowerby. *S. diemenensis*, C. M. M.	O.M.
107.	*Siphonaria cancer*, Reeve. *S. scutellum*, C. M. M. ...	O.M.
108.	„ *australis*, Quoy and Gaimard (?) ...	O.M.
109.	*Amphibola avellana*, Gmelin	O.M.

Lamellibranchia.

110.	*Saxicava arctica*, Linnæus	O.M.
111.	*Glycimeris zealandica*, Quoy and Gaimard. (Panopæa)	O.M.
112.	*Neæra trailli*, Hutton	—
113.	*Myodora striata*, Quoy and Gaimard. Not common	O.M.
114.	„ *plana*, Reeve (?). *M. brævis*, C.M.M. Not of Stutchbury	O.M.
115.	*Mactra discors*, Gray. *M. murchisoni*, Deshayes ...	O.M.
116.	„ *æquilatera*, Deshayes	O.M.
117.	„ *scalpellum*, Deshayes. *Darina pusilla*, Hutton	O.M.
118.	*Standella ovata*, Gray. (Hemimactra, C. M. M.) ...	O.M.
119.	*Mulinia elongata*, Quoy and Gaimard. (Spisula.) *M. notata*, Hutton	O.M

120. *Psammobia stangeri*, Gray .. .. O.M.
121. „ *lineolata*, Gray. Chalky Inlet ... O.M.
122. „ *affinis*, Reeve. *P. zonalis*, C. M. M. Not of Lam ... ... O.M.
123. *Soletellina siliqua*, Reeve. *Hiatula nitida*, C. M. M. Chalky Inlet ... ... O.M.
124. *Tellina alba*, Quoy and Gaimard. *T. albinella*, C. M. M. Catlin's River ... ... O.M.
125. *Tellina deltoidalis*, Lamark. Catlin's River ... O.M.
126. „ *decussata*, Lam (?) ... ... —
127. „ *lintea*, Hutton ... ... —
128. „ *ticaonica*, Deshayes (?) ... ... —
129. *Mesodesma novæ zealandiæ*, Chemnitz. *M. chemnitzii*, Deshayes. *M. ovalis*, Reeve. *M. novæ zealandiæ*, Reeve ... ... O.M.
130. *Mesodesma sub-triangulata*, Gray. *M. spissa*, Reeve. *M. cuneata*, C. M. M. Not of Lam ... ... O.M.
131. *Mesodesma lata*, Deshayes. *M. elongata*, C. M. M. Not of Quoy nor Desh ... ... O.M.
132. *Venus oblonga*, Hanley. Rare ... . O.M.
133. *Chione costata*, Quoy and Gaimard. Abundant ... O.M.
134. „ *stuchburyi*, Gray. *C. dieffenbachii*, Gray. Not so common as the last ... ... O.M.
135. *Chione mesodesma*. Quoy and Gaimard ... ... O.M.
136. *Dosinia anus*, Philippi. Rare ... ... O.M.
137. „ *subrosea*, Gray. Rare ... ... O.M.
138. *Tapes intermedia*, Quoy and Gaimard. (Venus) ... O.M.
139. *Cardium striatulum*, Sowerby. Rare ... ... O.M.
140. *Venericardia australis*, Lamark ; *V. tridentata*, Say (?) O.M.
141. *Lucina divaricata*, Linnæus. Chalky Inlet ... O.M,
142. *Loripes globularis*, Lamark (Mysia, C. M. M.) ... O.M.
143. *Kellia cycladiformis*, Deshayes (?) ... ... —
144. *Solemya australis*, Lamark. Stewart Island and Chalky Inlet ... ... O.M.
145. *Mytilicardia excavata*, Deshayes (?) ... ... O.M.
146. *Mytilus magellanicus*, Lamark (?) ... ... O.M.
147. „ *latus*, Chemnitz ; *M. smaragdinus*, C. M. M., *nec* Chemnitz ... ... O.M.
148. *Mytilus dunkeri*, Reeve ... ... O.M.
149. „ *ater*, Zelebor ... ... O.M.
150. *Crenella impacta*, Hermann. *M. discors*, Lamark ... O.M
151. *Modiola areolata*, Gould. *M. albicosta*, C. M. M., not of Lam ... ... O.M.
152. *Modiola securis*, Lam (?). Brackish water ... O.M.
153. *Pinna zealandica*, Gray ... ... O.M.
154. *Barbatia decussata*, Sowerby. *B. sinuata*, C. M. M., not of Lam ... ... O.M.

155. *Pectunculus laticostatus*, Quoy and Gaimard ... O.M.
156. „ *striatularis*, Lamark ... ... O.M.
157. *Nucula nitidula*, Adams. *N. margaritacea*, C. M. M. O.M.
158. *Leda australis*, Quoy and Gaimard (?) ... ... O.M.
159. *Solenella cumingii*, Adams. Rare ... ... O.M.
160. *Pecten zealandiæ*, Gray. *P. multicostatus*, Reeve ... O.M.
161. „ *gemmulatus*, Reeve. *P. dieffenbachii*, Reeve... O.M.
162. „ *radiatus*, Hutton. Not common ... ... O.M.
163. „ *convexus*, Quoy and Gaimard. *P. vellicatus*, Hutton. Rare ... ... O.M.
164. *Vola laticostatus*, Gray (Pecten). *P. novæ zealandiæ* Reeve. Rare ... ... O.M.
165. *Lima squamosa*, Lamark ... ... O.M.
166. „ *bullata*, Born ... ... O.M.
167. *Anomia alectus*, Gray ... ... O.M.
168. „ *cytæum*, Gray ... ... —
169. *Placunanomia zealandica*, Gray ... ... O.M.
170. „ *ione*, Gray ... ... —
171. *Ostrea purpurea*, Hanley ... . O.M.
172. „ *discoidea*, Gould. *O. lutaria*, Hutton ... O.M.

Brachiopoda.

173. *Waldheimia lenticularis*, Deshayes ... ... O.M.
174. *Terebratella cruenta*, Dillwyn ... ... O.M.
175. „ *rubicunda*, Solander ... ... O.M.
176. *Magas evansii*, Davidson ... ... O.M.
177. *Rhynchonella nigricans*, Sowerby ... ... O.M.

APPENDIX D.

TABLE of altitudes above sea level of natural features in the Province of Otago (selected from the trigonometrical determinations of the reconnaissance and minor triangulation surveys), by JAMES McKERROW, Chief Surveyor.

—		Above sea level in feet	—
Lakes.			
Ohau ...	...	1723	Depth unknown.
Hawea ...	...	1062	Depth 1285 feet, or 223 feet below sea level.
Wanaka ...	...	928	Depth 1085 feet, or 157 feet below sea level.
Wakatipu ...	...	1050	Depth 1350 feet, or 300 feet below sea level. The ancient outlet of Wakatipu Lake at Kingston is 175 feet above present level of lake, or 1225 above sea level.
N. Mavora ...	...	2073	
Te Anau ...	...	720	Depth unknown.
Manipori ...	...	623	Do.
Harris ...	...	3800	Do.
Taieri ...	...	986	Do.
Plains.			
Waitaki Valley	UpperWaitaki	1790	At trig. T near Benmore station.
	"	1990	At trig. I near issue of Ohau River, from lake.
	LowerWaitaki	571	At trig. U on Terrace at joining of Otekaik with Waitaki
	"	200	At trig. K on Papakaio Plain, opposite Big Hill.

		ABOVE SEA LEVEL IN FEET.	
Clutha Valley	Upper Clutha	1312	At trig. A banks of Hawea river
	"	700	Kawarau Flat, adjacent to Cromwell
	Manuherikia	1722	Junction of east branch, one mile above Falls on Manuherikia
	"	540	Dunstan Flat at Clyde
	Moa Flat	267	At trig. B near township of Ettrick
Ida Valley ...	...	1997	At trig. D alongside Coach road, $1\frac{1}{2}$ miles from Hill's Creek
" ...	...	1406	At trig. G on flat opposite Gorge of Idaburn.
Taieri Valley	Maniototo ... (Upper Taieri)	259	At trig. A on flat 2 miles north of where Taieri issues from mountains.
	"	2018	At trig. X near Naseby.
	"	1304	At trig. H on terrace near old crossing on Kyeburn.
	Strath Taieri...	914	At trig. E near Great Stone.
	Taieri ...	675	At trig. C, Sutton district, on banks of Taieri, and about the lowest part of plain.
	East Taieri ...	14	Floor of verandah, Adams' accommodation house.
	West Taieri ...	44	Top of masonry West Taieri bridge.
	North Taieri	28	Trig. A on edge of swamp.
	"	91	Trig. B
Mataura Valley	Waimea ...	627	Trig. A near Gowsburn, Waikaia Flat.
	Wakaia ...	450	Average level of plains near junction of Mataura and Wakaia.
		900	Summit of Pyramid Hill, near do. do.
	Lower Mataura ...	107	Trig. B on township flat Wyndham

—		Above sea level in feet.	—
Waiau Valley	Te Anau Downs and Mararoa Valley	600	Flat at junction of Mararoa and Waiau rivers.
		2010	Top of Terrace where Mararoa issues from bush.
	Waiau Plains	300	North end of plain, near Wairaki Stream.
	Terrace north side of Black Mount ...	1700	This terrace stretches across from Black Mount to Takitimo Mountains
Southland ...	...	177	At Geo. station, trig. P, Oteramika
	Passes.		
Lindis ...	...	3185	This is the lowest point on water shed between the Waitaki and Clutha river systems.
Oreti ...	...	2615	This is the lowest point on the water shed between Waiau and Clutha river systems.
West Coast Passes in use.	Haast ...	1716	This determination is given by Dr. Haast, and this pass is the lowest known point on the water shed between east and west coast of Middle Island.
	Harris ...	3900	Highest point on track between Head of Lake Wakatipu and Martin's Bay.
	Greenstone ...	2000	Estimated height of land between Greenstone and Hollyford Valleys.
Track from Arrowtown to Cardrona crosses Crown Range at ...		4300	The saddle at head of Cardrona is much lower than this, probably not over 3,000 feet.

——	ABOVE SEA LEVEL IN FEET.	——
Dunstan	3300	Lowest point on ridge between Dunstan Creek and Cluden.
Water of Leith Saddle	1190	Height of land between Water of Leith and Waitati Stream.
Look-out Point	378	The lowest point on ridge between Dunedin and Kaikorai Valley—coach road passes.
Coach road crossing of Chain Hills ...	415	The lowest point on Chain Hills—the dividing ridge between Kaikorai Valley and Taieri Plain.
Rivers.		
Clutha, at junction of Island Block Stream	172	This point is 57 miles from sea by channel of river.
Clutha half a mile below Ettrick	211	Do. 65 do.
Clutha Clyde (summer level)	460 (approx.)	Do. 100 do.
Cromwell (meeting of Kawarau and Clutha)	525 (approx.)	Do. 113 do.
Newcastle (meeting of Wanaka and Hawea branches of Clutha)...	906	Do. 145 do.
Issue of Wanaka Lake	928	Do. 148 do. Issue of Wanaka Lake is 122 miles in a straigth line from sea.
Comparative Fall of Rivers.		
Waitaki, from Ohau Lake to sea, falls ...	1723	In a distance of 93 miles by channel of river.

—	ABOVE SEA LEVEL IN FEET.	—
Taieri, from Taieri Lake to sea, falls ...	986	Do. 77 do.
Clutha, from Wanaka Lake to sea ...	928	Do. 148 do.
Mataura, from 7-mile crossing, near Kingston to sea, falls ...	1090	Do. 109 do.
Oreti, from where it issues from Thomson Mountains to sea ...	2500	Do. 106 do.
Waiau, from Manipori Lake to sea ...	623	Do. 60 do.
Line drawn across the summits of intervening mountain ridges between Dunedin and Martin's Bay: (this is the broadest part of Middle Island)		
Crosses Flagstaff Range at	1000	4 miles from East Coast. Flagstaff summit. 2192 feet.
,, Highest part of Sutton district	1900	28 miles from East Coast.
,, Rock and Pillar Range ...	3500	40 miles from East Coast Rock and Pillar summit, 4675 feet.
,, Rough Ridge ...	3800	50 miles from East Coast.
,, Obelisk (Old Man Range) ...	5500	74 do. do.
,, Double Cone ...	7688	100 do. do.
,, Earnslaw ...	9216	134 do. do.
,, Martin's Bay ...	0	164 do. do.

—	ABOVE SEA LEVEL IN FEET.	—
Miscellaneous		
Potter's sluicing claim, Wakaia	4000	This and Clark's diggings, Naseby district, also about 4000 feet, are the highest worked auriferous deposits in Otago.
Dooley's coal adit, Kawarau Valley ...	2000	This is the highest lignite working in Otago. In the same valley lignite has been discovered at an elevation of 3000 feet.
Forest line	3400	
Snow line	7500 to 8000	
Macrae's township ...	1700	These places have originated and are entirely dependent on the auriferous drift workings alongside of each. They are scattered over the interior of Otago, and represent nearly all the important known gold deposits within that region. The similarity of levels over such wide areas is suggestive.
Hamilton do. ...	1800	
Naseby do.	"	
Hill's Creek do ...	"	
St. Bathan's do ...	"	
Drybread diggings ..	1600	
Cardrona do ...	1800	
Terraces in Shotover Valley, at Maori Point, Skipper's point, and Upper Shotover ...	1650 to 1800	
Wheat is grown extensively in the lake districts, from ...	1000 to 2000	This is not to be taken as the limit of altitude for wheat in Otago.
Oats grown at all the interior townships of Otago up to ...	1800	This is not to be taken as the limit of possible oat cultivation in Otago.

APPENDIX E.

Analyses of Rocks and Minerals, by Professor J. G. Black.

Extracted from the Votes and Proceedings of the Provincial Council of Otago, 1875.

COALS.

Eight samples of hydrated brown coal were forwarded from the Tokomairiro coalfield, and without undergoing any previous process of drying, were analysed with the following results :—

Coke	from 37 to 41 per cent.,	averaging	39 per cent.
Fixed Carbon ...	,, 30 to 35.5 ,,	,,	33 ,,
Volatile Hydrocarbons	,, 31 to 38 0 ,,	,,	35.4 ,,
Ash	,, 2 to 9 ,,	,,	5 ,,
Water	,, 22 to 30 ,,	,,	27 ,,

Five samples of Lignite were sent at various times from different parts of the Green Island field, and without previous drying yielded the following results :—

Coke	38 to 41 per cent.,	averaging	39 per cent.
Fixed Carbon ...	35 to 37 ,,	,,	36 ,,
Volatile Hydrocarbons	30 to 37 ,,	,,	34 ,,
Ash	2.4 to 3.3 ,,	,,	2.8 ,,
Water	25.7 to 29 ,,	,,	27 ,,

A sample of hydrated brown coal from the Kaitangata coalfield, without artificial drying, yielded :—

Coke	42.1 per cent.
Fixed Carbon	38.7 ,,
Volatile Hydrocarbons	38.9 ,,
Ash	3.4 ,,
Water	18.0 ,,

A specimen was sent by Mr. McArthur from Nightcaps in Southland. On analysis it showed :—

Coke	45.3 per cent.
Fixed Carbon	41.8 ,,
Volatile Hydrocarbons	31 7 ,,
Ash	3.5 ,,
Water	23.0 ,,

IRON ORES.

Iron Sand.

Three samples of black iron sand from Stewart Island, Taranaki, and Tokomairiro. The iron ranges from 49 to 54 per cent.

Port Molyneux.

This specimen is hydrated sesquoxide of iron from Port Molyneux. It yielded :—

Water	14	per cent.
Oxide of Iron...	65.5	„
Earthy matter (clay silica) ..	20.5	„

This is equal to 46 per cent. of metallic iron. If there is a large quantity of this ore near a good coal field, it should take a good place among the industries of the future. The small quantity of silica present (about 10 per cent.) will not require much lime for its removal.

Maeruwhenua.

This sample was forwarded by Capt. Hutton. It is hydrated sesquioxide of iron of fair quality. It yielded :—

Water	7	per cent.
Sesquioxide	55	„
Earthy matter (chiefly silica) ...	38	„

The silica (about 20 per cent.) would require lime for its removal. Equal to 38.5 per cent. per metal.

Cromwell.

This sample consists of anhydrous sesquioxide of iron, specular iron ore, mixed with 30 per cent. of quartz and earthy matter. It yielded :—

Sesquioxide	70	per cent.
Silica	22	„
Earthy matter	8	„

This is equal to 49 per cent. of metallic iron. It is, therefore, if in quantity, a valuable ore.

Tokomairiro.

This speeimen was forwarded by Capt. Hutton from Tokomairiro. It is an excellent ore. On analysis it shows of—

Susquioxide of iron	79.5	per cent.
Water	14 0	„
Earthy matter	6.5	„

This is equal to 55.75 per cent. of metallic iron, and in such a state of combination and purity as to be very easily reduced. It will, if found in large quantity be a very valuable ore of iron, and should not be neglected.

COPPER ORES.

Carrick Range.

This sample was forwarded from Carrick by W. Buchan. It is copper pyrites, and contains 13.5 per cent. of metallic copper. It is at present unavailable, on account of the large quantity of fuel of good quality necessary for its extraction. From Cornwall similar ore of 5 to 10 per cent. of metallic copper is transmitted to Swansea for reduction.

Arrowtown.

This sample was forwarded from Arrowtown through Mr. Willis. It contains 11 per cent. of metallic copper, combined with sulphur and iron as copper pyrites, and containing much earthy impurities. It is too poor to be worked profitably at present.

Moke Creek.

This sample of copper pyrites was examined in September, 1873, for Mr. R. Gillies. It was obtained from Moke Creek, near Queenstown. It contains 24 per cent. of the metal, and is the best specimen of copper pyrites yet examined in this laboratory.

Another sample of copper pyrites from Moke Creek and one from Waipori forwarded by Mr. Ulrich, to be tested for gold, were found to contain that metal, apparently in payable quantity, but there was not in either case a sufficiently large quantity sent to determine the gold quantitatively.

ANTIMONY ORES.

Carrick Range.

These samples from Carrick were forwarded by Mr. Buchan, and were found to contain 50 to 54 per cent of antimony. The ore of this quality is too far in the interior of the country to be exported profitably. With good fuel, however, it might be freed from the earthy matters with which it is associated, and then conveyed to Dunedin for transmission to Melbourne, where there are, I believe, large works for the reduction of this ore (stibnite) to the metallic state.

Miller's Flat.

This sample of stibnite was sent from Miller's Flat by Mr. J. A. Grant in September, 1873. It was found to contain 58 per cent. of metallic antmony, but the sample examined was too small to be taken as an average of the bulk of ore.

Arrow.

This sample, forwarded through A. Willis, Esq., from Arrowtown. It contains 34 per cent. of metal, and is therefore too poor to work profitably.

MERCURY ORE.

Waipori.

This sample of Cinnabar, forwarded by Mr. R. Gillies, was was obtained from Waipori. It yielded 76 per cent. of metallic mercury.

Another sample was forwarded from Waipori, or Waitahuna, by Mr. Rutherford, and was found to contain 72 per cent. of metallic mercury,

Both these ores, if they exist in quantity, are very valuable. The metal is easily freed, by means of cheap fuel (dried scrub. &c.) and lime from the sulphur with which the mercury is contained in cinnabar. The extensive use of mercury in this Colony and in Victoria for the extraction of gold is an additional reason for not neglecting any ore of that metal that exists in the country.

Waitahuna.

A sample forwarded from Waitahuna, by Mr. R. Smith, contains from 70 to 75 per cent. of mercury, and is therefore very valuable.

Carrick Range.

This sample was forwarded by Mr. W. Buchan, from Carrick. It is the best sample of cinnabar yet analysed in the laboratory. It contains 82 per cent. of the metal. This ore is of great value if present in quantity.

PLATINUM.

Bluff.

A sample of this ore was forwarded from the Bluff in September, 1873. It consisted of from 35 to 42 per cent. of platinum, black or magnetic oxide of iron not estimated, and an alloy of platinum, osmium, and iridium. The ore, in its present state, is worth in London between 7s. and 9s. per ounce.

MANGANESE (Black Oxide.)

Taieri Beach.

A sample of this mineral was forwarded from the Taieri beach, by Mr. Hanning, in November, 1873. It was found to contain 90 per cent. of dioxide of manganese. It is, therefore, an excellent specimen of this valuable mineral. It will be very useful when we shall have established in this Colony the manufacture of chloride of lime and other substances that require for their production free chlorine. This will not be done, however, until we can make our own sulphuric acid.

OIL SHALE.

Orepuki.

This mineral was forwarded from Orepuki through Mr. Daniel. It was reported on in December, 1873, as follows:—Laminated, very fissile, greyish black, shale flexible in thin layers, densely speckled with mica scales, cuts easily with the knife with unctuous, waxy, section; inflames readily over ignited lucifer match, and maintains after removal of the match a long somewhat smoky flame; the shale shows no trace of woody tissue.

Distilled at low and gradually increasing temperature it yields 42 gallons of crude tarry oil to the ton of shale. This oil possesses the characters of petroleum. It melts at 30°C (86° F.), and at 15°C. (59°F.), has a specific gravity of 0.897. This crude oil, after treatment with sulphuric acid and caustic soda and redistillation, yields from 1 ton of shale 15.2 gallons of purified oil of specific gravity, 0.798 to 0.860, suitable for burning in lamps; also 7 gallons of oil of specific gravity from .86 to .93, suitable for lubricating machinery. At higher temperatures the residue of the above distillation yields a still heavier oil, also suitable for lubricating purposes; finally a liquid tar is obtained, leaving charcoal in the retort. The products of the first distillation are:—

Water	25	per cent.
Earthy residue and charcoal ...	49.5	,,
Crude oil	16.8	,,

Dunedin.

This shale was forwarded by Dr. Burns from Burnside, near Blueskin. It is of the same mineral nature as the Orepuki shale, described above. It yields per ton of shale 38 gallons of crude oil. This, when purified by redistillation, after treatment with sulphuric acid and caustic soda in succession, yields per ton of shale about 14 gallons of oil, fit for burning in lamps, and 9 gallons of heavy unctuous oil suitable for lubricating purposes.

If we could produce our own sulphuric acid and soda cheaply, it might be profitable to extract burning and lubricating oils from these shales. As it is, the price of imported acids and alkalis is such as to deter the proprietors of these shales from importing the retorts and other appliances necessary for this purpose.

FELSPAR.

This specimen was collected by myself, in Port Adventure, Stewart Island. The mineral occurs there in pieces, weighing from 1 lb. to 15 or 20 lbs. These fragments are derived from the disintegration of the granite. Tons of the mineral could be collected with little trouble. It will obviate the necessity of sending for felspar to other countries for pottery and porcelainware purposes. Acting on my suggestion, Mr. White, of Tokomairire, has sent for

a quantity of this felspar, and I understand it is found well adapted for these purposes. The mineral yielded to two of the students of the Laboratory, the following results :—

MR. WILL :

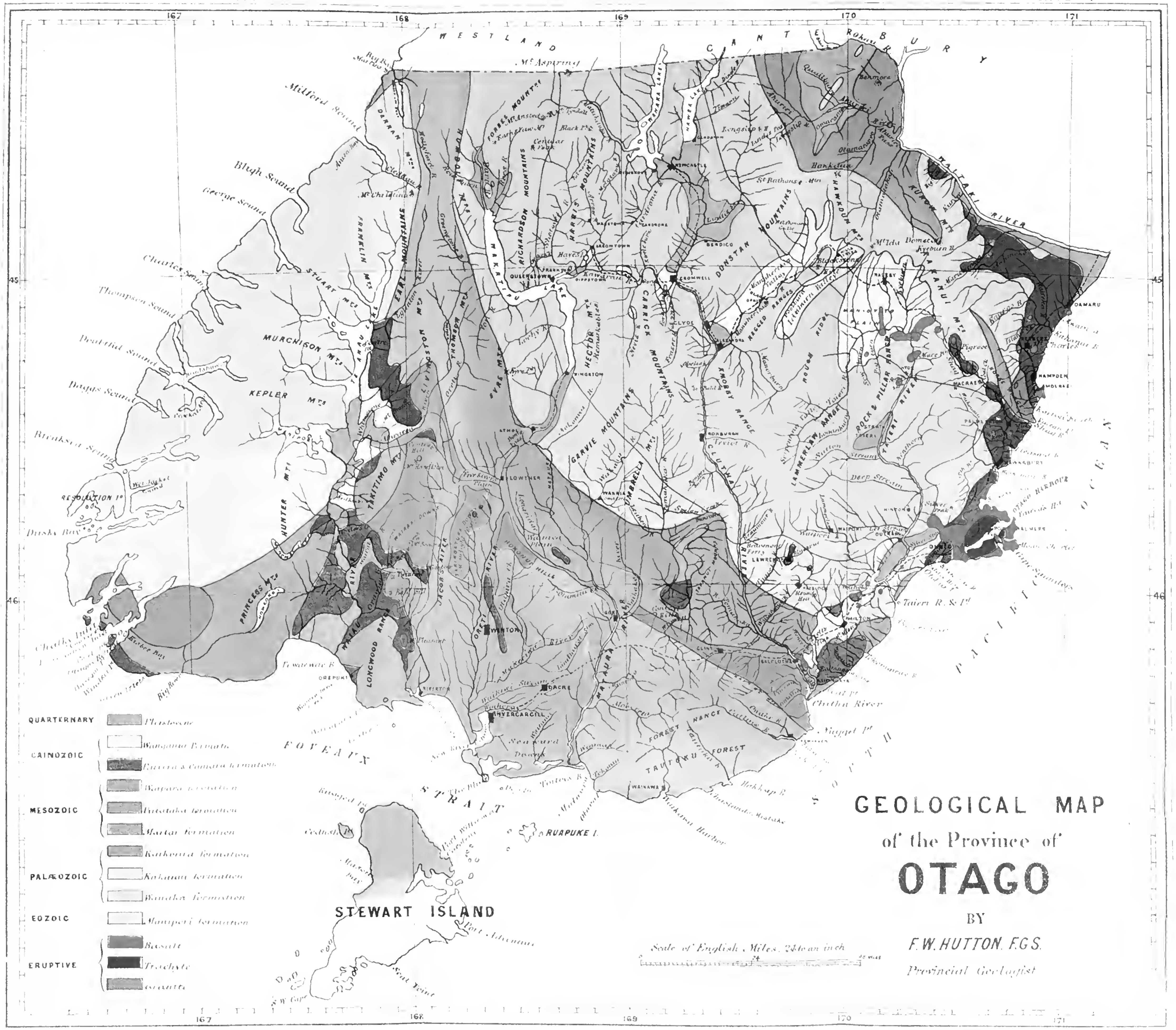
Silica	66.6	per cent.
Alumina	18.6	„
Potash	12.6	„
Soda	2.6	„
Lime } Magnesia } Traces.		
	100.4	

MR. SOLOMON.

Silica	58.1	per cent.
Alumina	22.0	„
Potash	11.9	„
Soda	4.3	„
Lime	4.7	„
Magnesia	0.28	„
	101.28	

The parts analysed were taken from different pieces of mineral.

The large percentage of alkali (15.2 and 16.2 per cent.) makes the stone an excellent flux for glazing in the Pottery Works.


GEOLOGICAL MAP
of the Province of
OTAGO
BY
F.W. HUTTON F.G.S.
Provincial Geologist
Scale of English Miles, 24 to an inch
QUARTERNARY
CAINOZOIC
MESOZOIC
PALÆOZOIC
EOZOIC
ERUPTIVE
Pleistocene
Basalt
Trachyte
WESTLAND
CANTERBURY
PACIFIC OCEAN
FOVEAUX STRAIT
STEWART ISLAND
RUAPUKE I.
Milford Sound
Bligh Sound
George Sound
Charles Sound
Thompson Sound
Doubtful Sound
Dagg's Sound
Breaksea Sound
Dusky Bay
RESOLUTION Id
MURCHISON Mts
KEPLER Mts
HUNTER Mts
TAKITIMO Mts
PRINCESS Mts
LONGWOOD RANGE
FRANKLIN Mts
STUART Mts
EARL MOUNTAINS
FORBES MOUNTAINS
RICHARDSON MOUNTAINS
HARRIS MOUNTAINS
DUNSTAN MOUNTAINS
CARRICK MOUNTAINS
GARVIE MOUNTAINS
HECTOR Mts
KNOBBY RANGE
ROCK & PILLAR RANGE
LAMMERLAW RANGE
FOREST RANGE
TAUTUKU FOREST
WAKATIPU LAKE
WAKATIPU
WANAKA LAKE
HAWEA LAKE
WAITAKI RIVER
CLUTHA
QUEENSTOWN
CROMWELL
CLYDE
ALEXANDRA
ROXBURGH
OAMARU
HAMPDEN
KAKANUI
PALMERSTON
DUNEDIN
OTAGO HARBOUR
MILTON
BALCLUTHA
GORE
WINTON
INVERCARGILL
LOWTHER
ATHOL
KINGSTON
Mt Aspiring
Chalky Inlet
Preservation Inlet
Nugget Pt
Clutha River
Taieri R.
Cape Saunders
Port Adventure
S.W. Cape
Foveaux
167
168
169
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45
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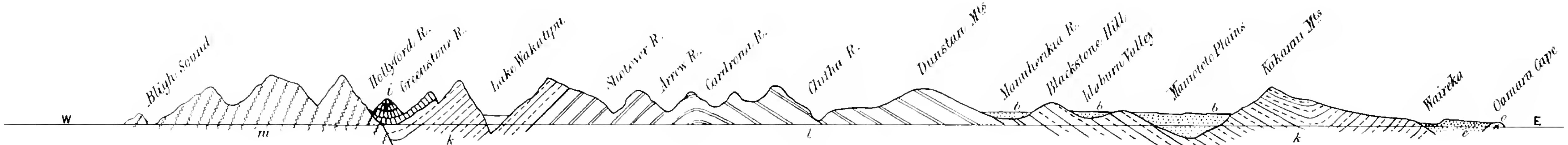
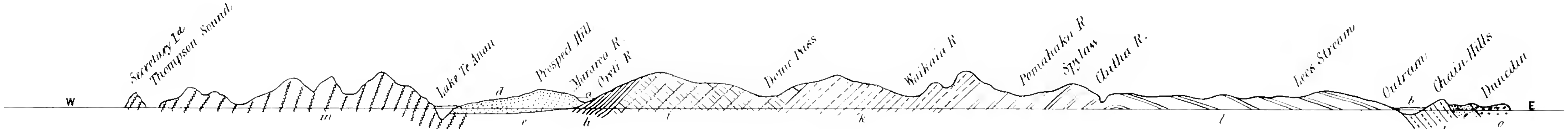
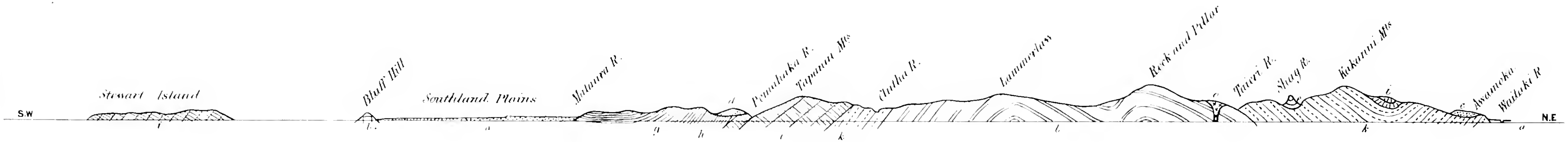


SECTION I DISTANCE 174 MILES



SECTION II. DISTANCE 196 MILES



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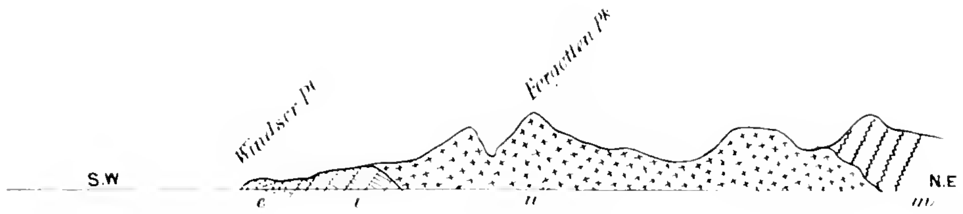
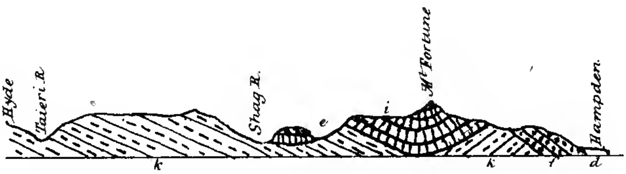


SECTION IV DISTANCE 28 MILES

SECTION V DISTANCE 50 MILES



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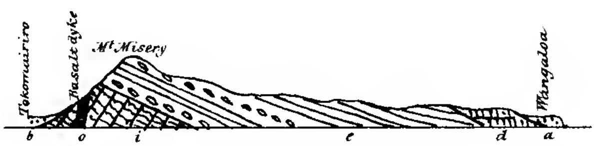
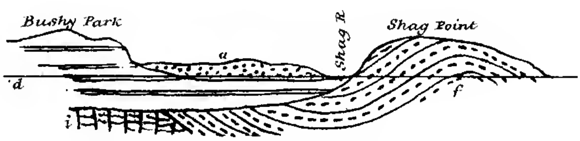
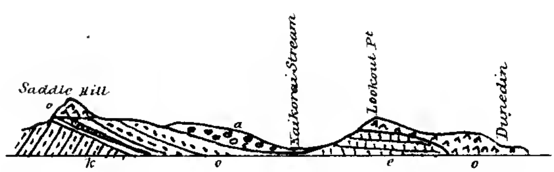


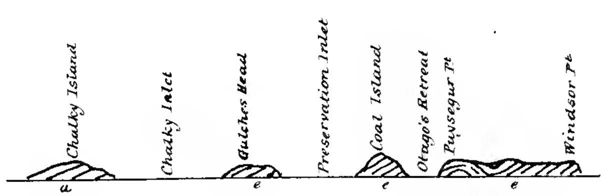
SECTION VII DISTANCE 9 MILES



SECTION VIII DISTANCE 2 MILES



SECTION IX DISTANCE 8 MILES



SECTION X DISTANCE 13 MILES

PART II.

GOLD FIELDS OF OTAGO.

By G. H. F. Ulrich, F.G.S.

INTRODUCTION

To His Honor the Superintendent of the Province of Otago.

Technological Museum, Melbourne, April 1875.

Sir,—I have the honor to submit herewith for your consideration the observations I made during my recent journey of inspection through the quartz mining districts of Otago. The instructions contained in your letter of the 21st December, 1874, were, that I should devote myself principally to an examination of the quartz workings, with the view of reporting generally on their geological relations, and more particularly in regard to any improvement I might be able to recommend in the mode of mining, crushing, or amalgamating, as would come within the scope and means of private enterprise; and further that, if not unduly trenching upon the time required for such examinations, I should pay attention to and afford information on the known occurrences in different parts of the Province of copper ore, cinnabar, antimony, and other minerals that came under my notice.

In obedience to these instructions, and mostly under the valuable guidance of Mr. D. MacKellar, the Secretary for the Goldfields, I have visited all the principal quartz mining localities of the Province, viz., Tokomairiro, Tuapeka, Waipori, Bendigo, and the Carrick near Cromwell, Arrow, Skipper's Creek, the Rough Ridge, Macrae's Flat, Shag Valley, Green Island, and Portobello, and besides examining most of the quartz reefs in work or opened, and the crushing mills existing in each district, I also made observations in certain localities on the auriferous drift deposits, and on the occurrences of copper ore, cinnabar, grey antimony, and on some of those—for Otago most important ones—of brown coal. Finding that in merely working out the copious notes taken during these inspections, very frequent repetitions would be unavoidable, more especially in my recommendations touching the working of the mines, crushing, and amalgamating, prospecting, etc., I thought it best to embody the principal observations and recommendations in a general report, throwing into appendices the special description of the mines, and certain information I have to afford on a profitable mode of burning brown coal for boilers, in a fireplace of novel construction, invented in Germany. Having, in forming my opinion on the reefs of the Province in their various stages of development, and more especially

with regard to their chances of carrying payable gold in depth, taken those of Victoria as my principal standard of comparison. I think it but fair to state my reasons for so doing. It will be remembered that a celebrated, perhaps the best, authority on the occurrence of gold in matrix in the older rocks—the late Sir Roderick Murchison—propounded in the third edition of Siluria, when speaking of the Victorian goldfields, the hypothesis that the gold in quartz reefs would gradually decrease in quantity downward, and ultimately run out, or at least become unpayable to work at a limited depth. His reasons for this prognostication were solely based upon mining experience in other gold mining countries. Nevertheless, the miners of Victoria worked courageously and successfully deeper and deeper, and thus in later years it was incontestably proved that gold occurred there in payable and even large quantities at depths which certainly did not deserve to be called "limited," Sir Roderick, in his last edition of Siluria, fairly withdrew from his original standpoint, acknowledging that the results of quartz-mining in Victoria put former general experience at fault, and inferring that quartz reefs of similar character and geological relations might offer similar chances of success in depth.

In more recent years the results of deep mining in Victoria have still more fully established the downward extent of the gold, and several reefs are there at present being profitably worked at depths approaching 1000 feet. Considering all former experience in gold mining in the matrix in other countries (California excepted), everything concerning mineral character, structure and behaviour of the auriferous quartz reefs of Victoria in depth, is therefore new to mining science, presenting, as it were, a new experience, fairly applicable in judging of the chances of similar quartz-reef occurrences elsewhere. And as I found the reefs of Otago to exhibit this resemblance—in many respects a very close one—to Victorian reefs, I shall, I think, be considered justified in basing my opinion of their prospects upon certain features exhibited by the latter in similar stages of development.

THE AURIFEROUS REEFS.

General Geological Observations.—As introductory to the description of the reefs, the following remarks on the nature of the country rocks in which the reefs occur, or gold has been found in matrix, will save frequent repetitions. With the exception of those of the auriferous locality near Portobello, specially considered further on, the rocks consist throughout according to my observations, and which are confirmed by Captain Hutton's, the Provincial Geologist's more extensive and detailed geological survey—of metamorphic schist, *i.e.*, argillaceous mica schist or phyllite, changing from the east towards the west into real mica schist, with subordinate bands of chlorite-schist, or chloritic mica schist. The line or

boundary where this change takes place has with difficulty been traced by Captain Hutton, but it appears that within the large district on the west, occupied by mica schist, there exists at least one rather large area, viz., the Carrick Range, where the rock conforms in all lithological respects to true phyllite, and this range lies, according to Captain Hutton, within the line of a main anticlinal axis. Whether this inlying patch of phyllite represents a remnant of denudation of an once superincumbent general formation on the mica schist, or whether it simply constitutes an area where the metamorphic action and change were of less intensity, remains a difficult problem, to be solved by future investigation. Only at two places within the extensive metamorphic district I obtained evidence of the existence of an intrusive rock, viz., high up the Carrick Range, in small dyke-and knoblike protrusions of a dark "hornstone-porphyry," and at Alexandra in several specimens of a similar porphyry, said to be derived from a reef-like out-crop (no doubt a dyke) on the northern slope of the Old Man Range. Mr. Coleman, of Alexandra, knows of several more dykes of this kind in other localities. Massive occurrences of granite, such as characterise the neighbourhood of most of the Victorian Gold Fields are, however, quite absent.

As a general rule, both the phyllite and mica schist, but more especially the latter, are rich in interlaminations of quartz, generally from less than one-fourth to near one inch in thickness, but sometimes assuming considerable dimensions—one to three feet in thickness—though with no regularity and permanency in strike and dip.

These generally lenticular-shaped masses, and, as a specimen shown me at Alexandra proved, also the small interlaminations of quartz, have at several places been found auriferous, which led to their being erroneously mistaken for true reefs or their leaders; and a considerable amount of money and labour has been wasted in their exploration. As a case in point, I may here notice the workings on the so-called Butcher's Gully Reef, near Alexandra. There, on a rocky, high table-land, consisting of nearly flat bedded mica schist, full of quartz interlaminations, a fine large shaft has been sunk 60 to 70 feet deep, and furnished with a pump worked by a water-wheel, which received its water supply by means of a long wooden flume from an extensive race on the neighbouring range. Gold at the rate of 6 dwt. per ton is said to have been crushed from the quartz, but as neither in the shaft nor in the stuff worked out of it, nor in the surrounding country, any indications of a reef are visible, the auriferous quartz found must no doubt have been derived from one or several of the small interlaminations, and the prospects of the place would, therefore, certainly not warrant further expense in more extensive exploration There are certain inferences to which the existence of these auriferous quartz interlaminations lead, namely, that they may be more frequent and more widely distributed

than hitherto supposed, and that the riches in gold of the drifts of the Province are in some measure, at least, due to their denudation. As regards the strike and dip of the schists, they are subject to great changes throughout the country, the former running through nearly all directions of the compass, and the latter from horizontal to vertical, from one side to the other; and these variations are in some places, as for instance on the Carrick Range, so frequent, and exist in such close proximity to each other, as to render the taking of any mean dip and strike quite a hopeless task. I have therefore, in the subsequent descriptions of the reefs, been in most instances obliged to give merely the relative position of the latter to the country—*i.e.*, whether they traverse the rocks either in strike or in dip, or in both. On the large scale there exists, as already mentioned, according to Captain Hutton's observations, a main anticlinal axis running nearly north and south through the country, including the Carrick Range in its course, from which axis the average dip of the rocks is on the one hand eastward, on the other westward; and in the latter direction, more especially between Arrow and Skipper's Creek, a more than usual regularity obtains in the westward dip, as seen in the ranges bounding the Arrow and Shotover Rivers.

Grouping of the Reefs.—The auriferous reefs opened throughout the Province differ very much, both in structure and mode of development; still there are some districts of which, though they lie rather far apart, the reefs show much resemblance to each other in the above respects; whilst again in other districts, comparatively close together, the difference in the nature and behaviour of the reefs is very great indeed. Taking advantage of these alliances, in order to simplify the description, the reefs and other occurrences of gold in matrix may be grouped as follows:—

1st Group: The Saddle Hill Reef, Green Island, near Dunedin; the Reefs of Tokomairiro (Canada Reef, &c.); the Gabriel's Gully Reef, near Lawrence; the O. P. Q. Reef, Waipori.

2nd. Group: The Reefs of Bendigo, near Cromwell; the Rough-Ridge Reefs; Conroy's Gully Reef, near Alexandra.

3rd. Group: The Reefs of Carrick Range.

4th. Group: The Reefs of Arrow and Skipper's Creek.

5th. Group: The Reefs of Macrae's Flat and Shag Valley.

6th. Group: Exceptional occurrences of gold in matrix—the so-called Peninsula Quartz Reef at Portobello.

1*st. Group: Saddle Hill Reef, Gabriel's Gully, O. P. Q. Reef, Canada Reef.*—These reef are true lodes, promising permanency in depth. They have well defined foot and hanging walls and clay casings or selvages, and cross the country (phyllite) both in strike and dip, though the difference in angle, either in strike or dip, or

sometimes in both, is generally not considerable. In their structure, development, and mode of occurrence they resemble very closely a certain class of Victorian reefs, called "Block Reefs," the typical characteristic of which is, that they are composed of generally a number of blocks of quartz, either with contractions of the lode fissures between, or, what is the case here, alternating with blocks of mullock—the latter term meaning gangue matter, consisting of country rock slipped into the lode fissure, where in course of time, it became more or less mineralised, impregnated with pyrites and traversed by small quartz veins. These quartz and mullock blocks, which reach sometimes considerable dimensions, extend hardly ever vertically downward, but show an endlong dip in strike within the fissures—north or south, east or west, as the case may be—in the same reef invariably, in the reefs of the same district generally, in the same direction. The feature may, in fact, be considered as an oblique banded structure on the large scale. In the reefs under notice the thickness of the blocks reaches in some cases 12 feet, and their dip in strike is generally at rather flat angles. According to experience, gold occurs both in the quartz and mullock blocks; but the former have hitherto invariably been found the richest, and in them its distribution is mostly not uniform throughout, but, as found in the Gabriel's Gully Reef, for instance, a rich small shoot dips at a flat angle across the block; or, as in the Canada Reef, a number of narrow, rich runs, dipping in the line of the blocks, are separated by poorer quartz; or, as in the Waipori Reef, a certain thickness on the hanging and foot walls is richer than the centre, &c. The appearance of the quartz, and this appertains also to that of the reefs of the other groups, varies very much according to whether the stone comes from near the surface or from beneath the water-level. In the first case it is white, opaque, and mottled and striped, with brown iron ore, or ferruginous slaty matter; in the latter it shows a bluish color, is slightly translucent and glassy, and full of blackish spots and seams of slaty matter, which, as well as the quartz itself, are more or less densely impregnated with pyrites. With the exception of the O.P.Q. Reef, Waipori, which produced from the old workings a very good average per ton, and promises richer yields from the new ones, the other reefs of this group are rather poor in gold, the yield ranging not much above 5 dwts. per ton throughout. Still, considering the thickness and extent of the quartz-blocks, the facility with which they can generally be worked, and that sometimes the intervening mullock is worth crushing, on account of thin rich quartz seams traversing it, they ought to be profitable to work—*i.e.*, on a larger scale than has hitherto been the case—for at least several hundred feet in depth; more especially if attention is paid to the saving and treatment of the pyrites; and the truth of this opinion is in some measure already shown by the results of the Canada Reef Mine, which, though worked by shaft on

a limited scale, produces from a depth of 80 feet, according to the manager's statement, a small profit from an average yield of 5 dwts. of gold per ton.

2nd Group: The Reefs of Bendigo, and the Rough Ridge, Conroy's Gully Reef, near Alexandra.—My reasons for grouping these reefs together are based more upon their exhibiting unmistakable structural differences from the reefs of the other groups than upon any similarity to each other in several aspects, touching mode of development and relation to the country. Their thickness is, in the average, but small, ranging generally from one-half to two feet, and exceeding rarely four feet, and, as far as workings have proved, they do not consist of solid quartz throughout, and but seldom so for any considerable extent in strike and dip (Logan's Reef). They represent, in fact, in certain respects, "block reefs," though with this difference from the true reefs of this class, that blocks of quartz and mullock of irregular size and outline are more or less irregularly intermixed, and do not, as those of the latter do, dip at certain angles, and in the same direction in strike. Most of the reefs of Bendigo show well-defined walls with clay casings, strike nearly uniformly east and west, are mostly traceable for long distances, and —what constitutes them very "strong" ones in mining sense, and indicates permanency in depth—they traverse horizontally, or very flat-bedded mica schist, vertically, or at very steep angles. The reefs of the Rough Ridge vary in strike, though not at large angles, and most are not traceable far in strike. They are generally not so well defined as those of Bendigo, and seem liable to frequent irregularities in strike and dip, contractions, and more especially to being faulted by slides; but these unfavourable features are apparently the results of surface disturbance only, and may disappear in depth. It is not uncommon, both at Bendigo and the Rough Ridge, that reefs split in strike into branches, which, though deviating at first from, assume gradually again the strike of the main reef, and run thus pretty close and parallel together, some increasing to the same, or even a greater thickness than that shown by the latter.

Besides "leaders" that dip towards them, so-called "droppers," dipping at generally flat angles away from them, have also been observed in some of the reefs at both places. With regard to the mode of occurrence of the gold, the comparatively superficial work done on most of the reefs hardly permits to form a definite and generally applicable opinion. Judging, however, from those most extensively and deepest worked, it would seem that the metal is accumulated in rich shoots of variable width, that dip at rather steep angles in strike in the quartz blocks; whilst the portions intervening between the shoots, including the mullock patches, are poor, but generally rich enough, or of such limited extent as to render it the most economical to work them with the rest, without resorting to special selection. Excepting the yields from Logan's

Reef, as unusually rich ones, those from the other reefs have been by no means low in the average, as they ranged up to 2 oz. per ton, and from hardly a single reef were they reported much below half an ounce per ton. Considering this, I was much astonished to see so many of the reefs and claims neglected (at the Rough Ridge over 20 claims were once worked, whilst at present only a single one); but the reason was explained to me to consist partly in the high prices charged for crushing, partly in expensive cartage, and more especially in the want of enterprising miners, those who worked the top having become afraid of the hard work and expense required in contending with the water. With regard to the prospects of the reefs in depth, I consider them, where the reefs are well defined, as very favourable, both as concerns persistency in auriferous character and regularity in average size. But in speculating upon profits to be derived from future working, several important points must not be left unconsidered, viz., the comparatively small size of the reefs, expenses connected with getting rid of the water, and greater difficulty in extracting the gold from the quartz; for below the water level, which lies in several of the reefs considerably higher than one would suppose from their elevation above the nearest permanent surface water, the seamy quartz is throughout very metalliferous; in fact, it promises at greater depth to become more highly charged with metallic sulphides (iron and arsenal pyrites, galena, zincblende, &c.) than in any of the reefs of the other districts I examined. Timely attention to improvements in the gold-saving appliances is therefore highly advisable. The expense of working narrow reefs will in depth also considerably increase, in consequence of the increasing hardness and closeness of the country, which latter is comparatively more unfavorable to work on account of its horizontal bedding. However, against this may be placed as a perhaps more than adequate set-off the high dip of the reefs, which much facilitates working, and, what is of greater importance, that the hardness of the rock, in conjunction with its horizontal bedding, renders the supporting of the workings very cheap and simple.

3rd Group: The Reefs of the Carrick Range.—The generality of these reefs present in several respects quite distinctive characters from the reefs of the other groups. They are peculiar clayey ferruginous "mullock reefs" or rather "quartz-mullock reefs," so soft that they can mostly be worked by pick without the aid of boring and blasting; and the quartz, which apparently forms no large per-centage of their mass, occurs only in the shape of coarse sand, and small angular and slightly rounded pieces—such reaching or surpassing the size of a fist being rather rare. Whether it represented originally interlaminations in the mullock, or was formed in veins, is uncertain, but a kind of banded structure in the line of dip of the reefs speaks in favour of the latter. These reefs vary in

thickness from less than 1 foot to over 6 feet; they strike in all directions across the country, but are only of short extent, and differ very much both in direction and angle of underlay—the latter ranging from vertical to less than 20°. Some of the reefs show also much irregularity in their course, for they expand and contract, twist and curve in strike and dip in quite a peculiar manner, and are—what is the case also with most of the others—frequently faulted by slides and cross-courses, so that it requires very great attention and perseverance on the part of the mining managers not to lose them. Considering all these points in connection with the fact that the country—a rather soft phyllite—is also very much disturbed both in strike and dip—steep and flat dips alternating and changing in direction within short distances—it appears next to certain that not only the peculiar soft and gravelly nature of the reefs, but also the exceptionally flat dips of some are not original, but due to strong pressure, friction, upheaval, etc.; and as the cause of these disturbances appears the most likely the intrusion of the dark hornstone-porphyry, which, as mentioned at another place, occurs in small knobs and dykes at several places on the range (near Carricktown.) Unfavourable as these features no doubt appear, touching straightforward and uninterrupted working of the reefs in future, I feel no apprehension of the latter giving out suddenly, or at a limited depth, for they are in every respect true lodes, crossing the country both in strike and dip, and showing the most frequently the hanging wall, less frequently the foot wall, and in some instances both walls well defined and separated from their mass by clayey casings, mostly polished and striated, representing the so-called "Slicken-sides," which afford unmistakable proof of movements of the wall of the reefs.

The gold, both in the quartz and mullock, is very fine, and, owing to the soft and ferruginous nature of the stuff, specks can but very rarely be seen during working. Judging from the crushings and occasional washing of prospects, it occurs chiefly in shoots dipping in strike, less in irregular patches, but seems also to be pretty generally distributed throughout the whole extent of the reefs, as far as opened. The yields of most of the reefs opened have in the average been very fair, as they ranged between ½ and 1½oz. per ton. On account of its softness the quartz mullock is easily crushed, but the saving of the fine gold requires great attention; and, as the supply of water, which the proper treatment of this kind of stuff requires, is rather above the average, but has at the existing machines been frequently much below it, and their saving appliances are not the most suitable ones besides, I am sure a great deal of the gold has been lost in the tailings. There is at the level of even the lowest workings not much pyrites observable in the reefs, still the ferruginous character of the mullock, as being no doubt a result of its decompesition, points to its former presence in large r quantities

and it may with certainty be expected to increase in abundance in depth. As regards the expense of working the reefs, the soft nature of both the mullock and country renders it small in one respect, viz.:—that of exploitation proper; in another, however, viz:—that of supporting the workings rather large, on account of the high price of timber, and the expense in this respect increases of course, in order to avoid accidents and collapse, the flatter the dip of the reefs. Fortunately there are on the field experienced managers and miners, well able to cope with this difficulty in the most economic and practical manner.

4th Group: The Reefs of Arrow and Skipper's Creek.—The only reefs in this group in course of being worked, and of which I was able to examine the workings, are "Southberg's" and the "Nugget and Cornish," Skipper's Creek; still, from examination of the outcrops of some reefs at Arrow, and information received about the character of a number of others once worked, but since abandoned, in both districts, I was enabled to form the following opinion on the general character of the group:—These reefs are true massive lodes, ranging from 4 to over 20 feet in thickness, which cut through the country both in strike and dip—the latter being generally steep—and show more or less well defined walls, with clay casings; a number are traceable for long distances – some for miles—in strike. In point of composition and structure they approach, however, far more mullock reefs than quartz reefs—they represent, in fact, fissures partly filled with *debris* from the country, full of interlaminated quartz, partly occupied by bunches and veins, of variable size, of true reef quartz. The mullock seems in the larger reefs to be generally predominating, and forms in places where their width very much increases by far the greater part of their mass—in fact, experience tends to prove that the thicker a reef is, or the wider it becomes the more mullock it contains, whilst on the contrary, decreasing thickness is connected with a relative increase in quartz, and the reefs become also better defined. The bunches and veins of reef quartz occur either on the hanging or footwalls, or on both walls, rarely in the centre. They appear to dip shootlike in strike, and are generally only in payable quantity within the line of the quartz shoots, or mineralized mullock, with its interlaminations and fine cross veins of quartz, has also, in all the reefs opened, been found to contain gold throughout, though generally only in payable quantity within the line of the quartz shoots, or where the reefs much contract in size. The yields have ranged from several dwts. to over 4oz. of gold per ton, but average from the reefs at present worked about 10 to 16 dwts. per ton. Although none of the reefs at Skipper's Creek have as yet been opened below permanent water level, they are already highly charged—both quartz and mullock—with pyrites, which seriously interferes with the satisfactory saving of the generally fine gold during crushing. This led the Phœnix

Company, after Mr F. Evans, the manager, had proved the payably auriferous character of the ore as such, to erect in connection with their crushing mill the necessary works for extracting the gold from the large quantity of it saved on long blanket strakes. The country is, with regard to most reefs, very favourable for their being easily and cheaply worked, owing to the highly precipitous nature of the mountains which they traverse, and the deep valleys and gorges from which they can be opened, either directly in strike, or by but short cross adits. Still there is at Skipper's Creek one serious drawback to regular systematic working, affecting the most important of the reefs within certain depths, namely, although the country rock —mica schist—appears on the large scale but little disturbed in strike and dip, it is throughout highly fissile, and traversed by numerous cracks and joints, and these features combined, aided by percolation and freezing of water, have originated enormous slips from the precipitous mountain sides—faults, in a certain sense—by which the continuity of the reefs is completely broken. In fact, nowhere on the slopes of those steep mountains can the miner be certain of having a reef exactly in its original place or unshifted. These disturbances, which render working dangerous and cause much expense in timbering, extend, however, to within the level of the nearest gorges or valleys only; below this, there is every probability of the lay of the reefs becoming less broken, though the existence of smaller faults and other irregularities must there also be apprehended, on account of the fissured nature of the country. As regards the continuance of the gold in depth, I see no reason to doubt it, yet I think it very likely that the doubtless increasing abundance of pyrites may, as in Victoria—and this refers also to the reefs of all the other groups—be connected with a corresponding decrease of fine, free gold in depth.

5th Group: The Reefs of Macrae's Flat and Shag Valley.—In point of definition and mode of occurrence these reefs, which I found all deserted, are, in my opinion, the least promising ones of the Province. Judging from those I could examine, and information about a few others that have been prospected, they represent either so called "layer-lodes," (Duke of Edinburgh Reef, Macrae's Flat, Shag Valley Freehold Company Reef), or are merely interlaminations between the beds of phyllite that forms the country in both districts.

Touching the layer-lodes, their general characteristics are that they strike and dip with the country, having the foot wall (one and the same bed of the country) generally pretty smooth throughout; but the hanging wall, mostly quite irregular, uneven and traversed by leaders. They are, on account of this mode of relation to the country, subject to all the changes in strike and dip of the latter, and, if these are great, are liable to frequent changes in thickness and can generally not be depended on for persistency in depth. In

the cases under notice, the stratification of the country is fortunately pretty regular, and all points are therefore in favour of the reefs being also more regular in course and thickness, and having a better chance of persistency in depth than is usually the case. Their dip is rather flat (less than 45°), and they are from 2 to 5 feet thick in the average, being composed of mullock and rather good-looking quartz; the latter generally predominating and occurring in bunches and veins mostly on the foot wall, or being irregularly intermixed with the mullock. The gold occurs both in the quartz and the mullock, though mainly in the former, and the yields have ranged from a few dwts. up to 2 oz. per ton, but did not pay in the average; therefore the reefs were abandoned at a very shallow depth. Considering that the gold did not run out, and that the reefs, as far as opened, show a good thickness for considerable extents, in connection with the circumstances under which they were worked, the advisability of giving them another more extensive and systematic trial certainly deserves consideration. With regard to the interlaminations, which were considered to be reefs, and of which some are in places several feet thick, they conform in all respects to what was said about these bodies in the beginning. That they are quite unreliable, concerning gold-bearing character and extent in strike and dip, is proved by the fact that, though several carried good gold (above 1 oz, per ton) near the surface, either their irregularity or impoverishment, or both cases combined, rendered working soon unpayable, and they were deserted in consequence, and, I may remark, do not invite renewed and more extensive prospecting.

6th Group: Exceptional occurrence of gold in matrix.—The so-called Peninsula Quartz Reef at Portobello.—These curious occurrences of gold which I inspected, in company with Captain Hutton, the Provincial Geologist, do not, though believed to do so, represent a quartz reef at all, but are, as far as the superficial workings and the reported results of trials allow one to judge, impregnations of gold in a finely divided state through various kinds of rock that will be described farther on. In a geological point of view, this auriferous locality and neighbourhood are the most interesting I have seen during my visit, and would well deserve a special detailed topographical and geological survey. True trachyte, trachyte-breccia, and tufa, and indurated ash-beds, broken through by dykes, and irregular dyke-like masses of basalt, compose principally, as it seems, that part of the Peninsula; whilst sedimentary rocks—sandstone and limestone—the geological relation of which requires yet to be determined, form apparently a narrow strip between it and the mountain on which Mr. Larnach's mansion is built. This mountain, consisting in its upper part of trachyte and basalt intermixed, seems, from half-way down its slope, towards the base, to be composed of sandstone, which in a small quarry is clearly seen to dip underneath the volcanic top rock.* As regards the places

* See anti page 48.

opened—four in number, in three of which gold has been proved by trial crushings to exist—they lie pretty nearly in a line (the supposed line of reef) down the steep slope of a mountain, at that part composed of greyish-white trachyte. Progressing from above downward, the place highest up the slope consists of an old saw-pit, from which a short prospecting drive has been put into the mountain. Quartz of a rather concretionary character was here found in the shape of an irregular bunch, enclosed with trachyte—the whole quantity lying about amounting to about one ton. In this no gold was seen, and no trial was made of it, but a specimen has been reserved for assay. The second opening, about 100ft. lower down hill, is a small, shallow excavation in trachyte, which is here full of siliceous segregations of irregular outline—some nearly one foot in diameter—of a quartzite-like character and bluish white colour ("bastard quartz," in miners' phrase), in which very fine grains of pyrites can be seen in abundance. Of this stuff two trial crushings, one of 2 cwt., gave 18 grains; the second, of a ton, yielded ½ oz. of gold; and Messrs. Forbes and McAuley, the prospectors, who kindly showed us over the ground, affirmed that they could wash a pretty fair prospect of fine gold from every tin dishful of the small stuff excavated. In the third opening—a small open cutting, some 60ft. below the previous one—very close-grained white trachyte was excavated, of which a trial crushing of a ton yielded 3 dwts. of gold. The fourth and last opening lies at the foot of the mountain, and consists of a good shaft of 40ft. in depth, with a small drive at the bottom. It penetrated for the first 25ft. through loose ground, and the last 15ft. through a decomposed cap into a hard coarsely crystalline rock, composed of hornblende, triclinic feldspar, and some quartz, and being more or less densely impregnated with very fine grains of pyrites. This rock continued also in the drive. Three trials were made, viz:—Two of the hard rock of 1 ton and ½ ton, which yielded respectively 8 dwts. and 11 dwts. of gold; and the third of 1 ton of the softer decomposed cap-rock, which gave, strangely enough, only 6 dwts. of gold, whilst generally decomposed portions of pyrites-bearing rocks are richer than undecomposed ones. All the recorded trial crushings were executed at a good battery in Victoria, and, in order to remove further doubt about the genuineness of this strange auriferous character of the quartzose, white trachyte, and the rock from the shaft, several small samples were most carefully tried in Dunedin, and these all produced gold. Accepting the auriferous character of the rocks, therefore, as satisfactorily proved, and considering that between the places opened there exists virtually not a feature such as would indicate a narrow auriferous zone or streak in their line down the mountain side, whilst it would seem very improbable that just per accident the auriferous portions of the rocks were opened and exhausted, we must come to the conclusion that there is a

great likelihood of the gold being generally disseminated—richer and poorer in places—through these peculiar varieties of rock as far as they extend. As the matter stands, the average results of the washings from Nos. 2 and 4 workings are certainly such that, taking into account the facilities the ground offers for mining, abundance of timber close to, etc., they should render working on a large scale, with ample crushing machinery near at hand, highly payable. Considering this, it would be really deplorable if the still lingering doubts in the reliability of the results of the trials made, *i.e.*, whether the gold really came out of the stuff and not out of the crushing machine, were not definitely set at rest by a further and more extensive trial—say of 10 to 15 tons from each of the two good places.

Strange as the occurrence of gold in such matrix, and under such circumstances, no doubt appears, it is in reality not without its alliances—at least, in certain respects—both in another part of New Zealand and in foreign countries Captain Hutton, who is intimately acquainted with the Thames Gold Field, North Island, recognised at once a certain resemblance between the geological features of the locality under notice and those of the Thames district. He thought the greyish white trachyte of the former looked much like the gold-bearing trachyte-tufa of the Thames, though there, as well known, the gold is found in bunches and veins of genuine quartz, and does not occur finely disseminated through the mass of the rock. The hard crystalline rock of No. 4 workings he also considered similar to a rock of which dykes traverse the auriferous tufa of the Thames, but which itself has not been found auriferous. As regards my own experience touching this rock, I think the latter bears considerable resemblance to certain trachytic rocks (trachyte greenstone) which I have seen on a journey through Hungary and from Transylvania, and which are there rich in auriferous silver and lead lodes. But from comparative examinations of specimens, I can also state that in mineral composition it is quite identical with, and in appearance hardly distinguishable from, the quartzose diorite-greenstone of some of the dykes which in Victoria traverse upper Silurian rocks, and are themselves traversed by generally highly auriferous quartz veins. That the rock is, notwithstanding this latter close resemblance, of volcanic origin, and represents in reality "trachyte greenstone," there can hardly be a doubt, however, on account of its mode of association with the typical trachyte of the locality. For besides in the shaft, close round which the greyish white trachyte is plainly exposed, outcrops of it (the greenstone) have also been found at several places in a neighbouring gully which cuts through trachyte, and on the slope of the trachyte range. According well with this opinion about its origin, and what it lithologically represents, and further showing the importance of this kind of rock, is what the celebrated

geologist Von Richthofen reports from the Washoe country and other parts of America, namely, that the rock there most prolific in gold and silver lodes is a volcanic rock of the trachyte series, closely allied to diorite both in composition and appearance, and for which he proposes the name "Hornblende propylite." Considering all the foregoing observations in connection, there exists, besides what we already know of their auriferous character as such, the chance that any quartz reefs or veins found traversing the trachyte and trachyte-greenstone in the locality under notice, or, in fact, wherever they occur, may prove highly auriferous. And on this account not only the neighbourhood of the workings, but the whole of that part of the Peninsula is well worth a thorough prospecting. The shore line showing the rocks generally plainly exposed offering in this respect special advantages.

Modes of Opening and Exploitation of the Reefs.

Opening of the Reefs.—As the steeply mountainous, rugged, and broken character of the country where most of the reefs are situated affords special facilities for their being opened and worked by adits, or tunnels, as they are generally, though incorrectly, called,* this method has extensively been made use of, and there are but a few reefs which had by necessity to be opened by shaft (Saddle Hill Reef, near Dunedin; Criterion Reef, Arrow—lying in low flats), or for which economic reasons, obtaining of quick returns, &c., rendered shaft sinking the most advisable at the start. Touching the facilities afforded by the adits in working the reefs, they are in all cases, no doubt, more or less considerable, according to circumstances; but with regard to positive advantages in a money point of view—considering in comparison the cost of working by shaft to the depths the adits come in—they appear in some instances very doubtful, or are quite on the side of the latter method. Want of water power, and great expense connected with employing steam power for hoisting the stuff and pumping the water, as also the procuring of easy transport of the stuff to the crushing machines, formed in these cases the main reasons for driving the adits; but then some of the latter might, at a comparatively but small increase in expense, have been at once put in much lower, or more careful calculation and scrutiny of circumstances at the outset would, in another case, have clearly shown that the length, respectively to the cost of the adit, was out of all proportion to the small height of reef overhead available for working, and that the water difficulty might at that depth have easily been overcome by horse-whim. It is not, of course, possible to lay down special rules, applicable in all cases, touching the advisability of opening

* To be tunnels, in the strict acceptation of the term, they ought to run right through the mountains, each connecting two points on the surface, which none of those under notice do.

reefs by adit instead of shaft, for local circumstances differ, and monetary reasons come into play; however, I may draw attention to several general or, as it were, starting points that ought never to be left out of sight in the consideration of cases in point:—

1. If adits can be driven direct in the lines of strike of reefs in which the gold occurs in such a way that they (the adits) prove productive workings from the commencement, they offer the greatest advantages as compared to shafts.

2. Where the direction of an adit would have to be at right angles, or obliquely against a reef, representing dead work, the whole capital required in its construction must be considered as lost, or calculated as part working expenses of the portion of the reef available overhead, if, when this is worked out, a new lower adit can be driven for working the reef under foot; for it (the upper adit) is thereby generally rendered quite useless. It maintains, of course, a certain value, if shaft sinking from it, and erection of hoisting and pumping machinery in a chamber constructed inside, have to be adopted for deeper working. But in such cases it is generally questionable, considering the discomfort and greater expense of this method, whether the working by shaft from the surface might not in reality have been the cheapest at the start.

3. Whilst every lower adit will generally be much longer, and consequently more costly than the preceding higher, useless one, and take a longer time in construction, a good shaft remains permanently useful for direct deeper working, and in the generality of cases a new block of reef will thereby be opened far sooner and cheaper than by a long adit coming in at the same depth. Where adits are considered the most advantageous, and the prospects of a reef underfoot of an upper adit warrant it, an intended lower one should by rights always be commenced at the same time as the exploitation of the reef above the upper adit, in order to render the interval between the productive periods of working as short as possible.

4. In case of the abandonment of a mine, the machinery attached to a shaft has always a certain value.

These several considerations on the question of "shaft v. adit" are only intended, however, to bear on the real opening and working of single mines. Shafts are out of the question in the case of large main-adits, intended for working several adjoining mines or of draining them of water, or of such to be driven for prospecting purposes at considerable depth across the country. For both these kind of adits, the Carrick, Bendigo, and Skipper's Creek districts offer special inducements and facilities; and whilst at Bendigo a deep Tunnelling Company is already in operation, another is contemplated to be formed at the Carrick Range. Particulars about these are given in the respective appendices.

Exploitation of the Reefs.—The method of exploitation, or of working the reefs, practised in the progressive mines of the different reefing districts, is, one single case excepted, "over-hand stoping," and I must say that, unless the broken nature of the ground prevented it (Nugget and Cornish, Skipper's Creek), wherever the mines were far enough advanced (most of the mines on the Carrick reefs), I found this mode of working carried out systematically and with due regard to rendering levels and winzes safe, by timbering and filling worked-out places with mullock. The exceptional case alluded to is Logan's Reef mine, which, considering the small width of the reef, is, contrary to the general mining rule, worked by "underhand stoping," and very economically, I must admit, yet, in a certain measure, at the expense of safety to the workmen, by not properly filling the worked-out spaces with waste. Speaking generally, this method, which is only practised in very wide lodes (2 to 3 fathoms)—for instance, in Cornwall—has, no doubt, many advantages over stoping overhand; but also very serious disadvantages. As the principal advantages may be mentioned, that working, by being carried on downwards, is easier, allows the use of heavier tools, and the men stand secure and convenient, whilst in over-hand stopping, it is more inconvenient and tiring, though the weight of the rock, in acting downwards, facilitates it; it is also more dangerous, especially in jointed, fissured, and loose ground, as the men have to work underneath. The disadvantages of the underhand stoping consist chiefly in the great expense entailed by the necessary timbering and mode of disposing of the waste in filling up of the worked-out places, it (the waste) having to be piled on platforms in front of the stopes. Next comes, that more manual labour is required in raising the ore from stope to stope, that the miner has to contend with water, and is often troubled with bad air. These drawbacks are so serious that, according to mining report, the method comes more and more out of use, and is likely to be soon entirely superseded by overhand stopping. As working is at present being carried on in the progressive mines I examined, hardly anything is done in prospecting the country in the hanging and foot walls of the reefs; but as this is of great importance and often very profitable, touching the discovery of rich, small companion reefs, branches and leaders, the driving of occasional small crosscuts ought not to be neglected. Before leaving this subject I have to draw special attention to one great defect I found in the management of most of the mines, namely, the non-provision of correct and detailed plans of the workings. I need not enter upon detailing the advantages such plans have in the systematic management of a mine, and the understanding and tracing of occurrences of unforeseen mining features (faults, turns, breaks of the reefs, etc). Every experienced mining manager knows these well enough. But I must say, that before entering upon the driving of adits, preliminary mining surveys of the

ground, and the preparations of working plans, are quite indispensable, in order to avoid false conclusions as to distances, errors in direction, etc. (See Lucknow Reef in appendix 6). The reason of these deficiences hitherto consists, I was informed, in the want of qualified mining surveyors, and considering the importance of the subject, I would therefore take the liberty to recommend the Government to appoint several surveyors of this class for the principal mining centres. Touching the duties of these gentlemen, they might, as is the case in Victoria, consist in the surveying of leases and claims, and in the execution of over and underground surveys, all which, as private work, to be paid for by the parties requiring it, whilst, during intervals between such work, the preparation for the Government of detailed topographical plans of the mining districts, to aid geological examination, might be carried on at certain fixed rates.

Chances of Prospecting for Auriferous Reefs.

As regards the chances of the occurrence of other auriferous reefs in the districts under notice, I consider them to be very good. In the neighbourhood of Saddle Hill Reef, several (4) good-looking, strong reefs crop out, which, as superficial prospecting has already proved them to be slightly auriferous, might likely yield payable stone on being tried at other points in their lines of strike. But besides this, there is in my opinion a very good chance of the existence of an auriferous reef about the head of a highly auriferous gully, worked abreast of the Saddle Hill Reef, on the right hand side of the main road leading from Dunedin to the Taieri. In the neighbourhood of the Canada Reef, Tokomairiro, the finding of rich quartz specimens outside the lines of the reefs opened, coupled with that of rich, nuggety gold in the north branch of the Tokomairiro River, is pretty good evidence of the occurrence of other auriferous reefs in that district. That the Gabriel's Gully Reef should be the only auriferous one in the Tuapeka district is also very unlikely. And, touching the country round Waipori where no systematic prospecting seems to have been carried on at all, I feel quite convinced that good reefs exist besides the one in work—not only in the neighborhood of the latter, but also in the ranges on the opposite side of and about the head of the Waipori River,—in order to account for the gold in the drift of the Waipori Valley, the angular specimens of auriferous quartz, and the patches of highly auriferous angular drift found here and there in the ranges. At Bendigo, the Carrick Range, the Skipper's Creek, the tracing of auriferous gullies and quartz specimens led, I was told, to the discovery of most of the principal reefs worked, though some showed by no means plain outcrops at the surface, partly by reason of their mullocky character, partly on account of being covered by detritus or being disturbed. And these features are the most serious obstacles

the intelligent prospector has to contend with in these districts, for that the latter are promising fields for further discoveries of quartz reefs is plainly indicated by numerous auriferous alluvial gullies and creeks, and the occurrence of quartz specimens outside the drainage range of the known lines of reefs. The recent discovery by tracing specimens of a new reef in the Bendigo district presents a case in point. The same reasoning, based upon similar data, applies more or less to all the other reefing districts (Arrow, Rough Ridge, etc.). And not to them alone, but also to the north and south slopes of the Obelisk Range, and to the rich alluvial diggings dotted along the edges of the Manuherikia, Idaburn, Upper Taieri, and other main valleys, though the reefs that in the latter cases supplied the gold to the drift would most likely lie in the ranges at the heads of, and bounding, the permanent creeks and rivers, entering the main valleys at, or in the neighbourhood of, the diggings. With regard to accepting the occurrence of massive auriferous drift or of mere surface at any place in rangy country as a promising indication of the existence of auriferous quartz reefs in the neighbourhood, the prospector ought to pay special attention, however, to one point, namely, to the nature of both the drift and the gold, *i.e.*, whether the pebbles and gold-specks are waterworn or not. For, if the first is the case, the deposit may be a remnant of a former terrace formation, far transported from its original source; whilst the more angular the stones, the more hackly and crystalline the gold-specks are, the nearer lies their place of derivation. There is one district (I had no time to visit it) hitherto only known as an alluvial diggings, which, according to information kindly afforded me by Messrs. L. H. Preston, Jenkins, McDougall, and Smith, of Arrow, presents first-class indications of being a good reefing district. This refers to the 12-Mile Creek diggings, and mainly to the Great Barrier Range, in which the Arrow and 12-Mile Creek take their rise, and that forms the water-shed between them and the Shotover River, the position of the tract being pretty nearly in the line of strike of the Skipper's Creek Reefs. A big reef runs right along the top of the range, and in the drift of the top part of the 12-Mile Creek, Scanlan's Gully, Specimen Point, and in that of Rodger's Gully and Tobin's Point, at the head of the Arrow River, rich quartz specimens were frequently found, and shown at the stores and banks of Arrowtown, whilst at certain points in the 12-Mile Creek large quartz blocks can be seen—one of nearly ½ ton in weight—showing fine specks of gold all over. The gold obtained from Rodger's Gully was generally so quartzose that it required careful crushing and separation of the quartz before it could be sold. Lower down country, about ½ mile from the junction of the 12-Mile Creek and Arrow River, a mullock reef, full of quartz veins, appearing as a wall-like formation on the mountain side, was cut through by a race, in which it proved to be 8 feet thick, show-

ing well defined walls, and dipping nearly vertical. Its promising appearance led a party of miners some time ago to prospect it, but, though the gold was found in the stuff, they deserted the reef again, and no work has been done on it since. Strong evidences of auriferous reefs are said to abound in many other places on the Arrow River and over the 12-Mile Hill, and only await the pick of the enterprising prospector for their development.

Concluding with a general comparison between this Province and Victoria as to the facilities and chances of prospecting, I must say that this work—looking at it in a strictly mining point of view only—is here much more difficult than in Victoria; for, whilst there, reefs consist mostly of massive white quartz, and are plainly exposed on the surface, they are here more frequently of a mullocky character, and more or less covered over by detrital matter. And there is besides one striking difference between the two countries, namely, that whilst in Victoria reefs abound all through the goldfields, but, as the saying goes, ninety-nine in a hundred prove barren, here they are comparatively very scarce, but with this redeeming feature, that nearly everyone hitherto found has proved to be auriferous, and therefore, we may fairly assign the same chance to any ones discovered in future.

CRUSHING MACHINERY AND GOLD-SAVING APPLIANCES.

The number of crushing machines erected and in course of erection at the different goldfields I visited, amounts to twenty-one, eighteen of which—including two near completion—are for quartz crushing, whilst the remaining three—including two in course of erection—are for crushing the cement of the Blue Spur.

Crushing Machinery.—Speaking of the crushing machinery proper, all these machines are, with but slight variations, constructed after the same model, viz., they consist of batteries of revolving stamps, four and five in a battery, working in cast-iron coffers on false bottoms, and being partly fed by hand, partly supplied with self-feeding hoppers. As far as I could see, they are well and substantially erected, the comparative freedom from jar of those I found at work proving their stability, and that due care had been bestowed upon the preparation of their foundations. At one or two machines the discs on the shanks were not quite in order, and the wipers too long, but the managers knew of these defects, and were going to repair them. On the, at one time in Victoria, much discussed question, whether round stamps are equal in crushing power to square ones, I need only remark that careful experiments under equal conditions have proved that they are nearly, if not quite, as effective as the latter, whilst the wear and tear, in consequence of the turning, is in the average less. In the weight and lift of the stamps and the speed at which they were driven, there were considerable differences between the machines, the weight ranging from four to seven cwt., the lift from five to eight inches, and the speed fifty-six to eighty-

five blows per minute. As regards the most advantageous weight for stamps, opinions are still divided in Victoria; still, heavy stamps are, on account of greater efficiency on the generally hard quartz, the most in use. In my opinion, a medium of about $5\frac{1}{2}$ to 6 cwt. would best suit the character of the stuff of most of the Otago reefs, though for such, consisting principally of hard, more or less solid, quartz—as, for instance, Logan's Reef, &c.—stamps up to 8 cwt. would, no doubt, be preferable.

Touching the height of drop and speed of the stamps, the former should not be less than seven inches, and might advantageously be increased to nine inches, especially if the stamps are light; whilst, touching the speed, it is generally considered best at the rate of 75 to 80 blows per minute. On the amount of stuff crushed during a certain time I could not obtain any definite information, but the figures given seemed to me to be rather low, and in order, therefore, to show what ought to be done under certain conditions, I may mention that at the Port Phillip Company, Clunes, stamps of 6 cwt., driven at a speed of 75 blows per minute, and with a drop of eight to nine inches, crush in the average 2 tons 4 cwts. per 24 hours; whilst others of 8 cwt., with the same fall and speed as just given, are expected to reduce each up to 4 tons per diem. Regarding the iron coffers, they seemed to me rather, if not too shallow for both economic and effective working. They allowed hardly one inch of loose quartz to be put beneath the false bed plates, and it would, therefore, require the greatest care in the placing of these plates, the feeding, &c., to prevent the plates from working unevenly into the shallow gravel bed. In fact, I think it can hardly be avoided that they (the plates) come frequently in contact with the iron bottom, the result of which, of course, is, as the sound of the blows already indicates, ineffective working and great wear and tear—sometimes even an unexpected breaking of the coffers. On this account I think it would certainly be advisable to have the latter, say, about two inches deeper, so as to allow a gravel bed of three inches beneath the false bottoms. Considering that the office of these latter is not only the saving of the coffers from wear and tear, but mainly to prevent the gold from being smashed too fine or "beaten dead," as it is called, they should only be of the same size as the stamp-heads, in order to leave sufficient space around them for the liberated gold particles to get into the gravel out of reach of the stampers.

The provision of self-feeding hoppers—a great desideratum for saving labour—has been neglected at a great number of the machines, and would deserve early attention. Many practical quartz crushers consider, and no doubt rightly, that hand feeding, if properly executed, is more effective; still it is extremely doubtful whether, especially in the case of small machines, the value of the increase in the quantity of stuff crushed is equal to that of a man's

labour; in my opinion, this labour is far more profitably applied to attending upon the gold-saving appliances. With only one or two exceptions, I found the great defect of the coffers having only front discharge; for it must stand to reason that, as it is, or ought to be, the aim to get the finely crushed material quickly out of the boxes, large escapes both in front and at the back are the most effective. Of course, such a double discharge arrangement necessitates a corresponding increase in the quantity of water to be supplied per stamp-head—a supply of from five to eight gallons per head per minute, regulated according to the weight of the heads and the nature of the crushing stuff, would, however, satisfy all requirements. The guage of the gratings, varying at the different machines from 122 to 144 holes per square inch, is, I think, scarcely well adapted to the nature of the stuff treated; for, as the gold is mostly very fine, the gratings should be very fine also, in order to ensure the necessary degree of reduction for a satisfactory liberation of the gold particles. Gratings with 169 to 196 holes per square inch would certainly be safer.

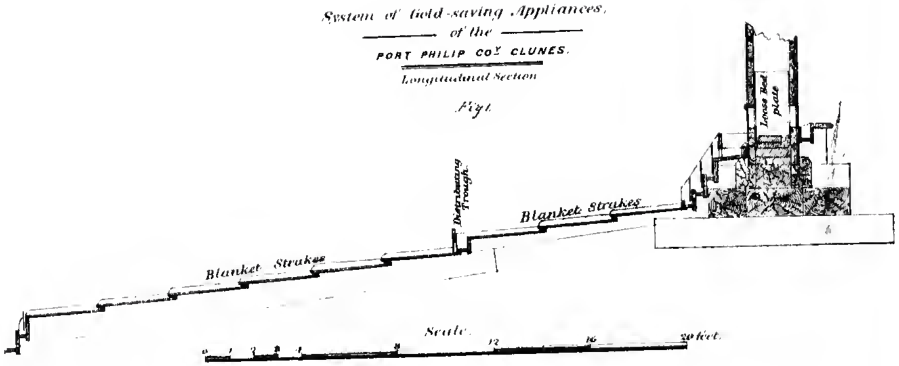
Gold Saving Appliances.—As regards the gold saving appliances in use, they consist, with the exception of two machines, which have drop-ripples attached, of amalgamated copperplate tables, in some instances with improvements in the arrangement of the ripples, and all, except the cement crushing machines, have various lengths of blanket-strakes succeeding. During working, it is the regular custom to put quicksilver into the stamper boxes. For the treatment of the blanket sand serve the common revolving barrel with shaking table or ties attached, dolly tubs, small berdan machines and simple ties, though the latter inferior appliances at a few machines only. Although generally well constructed and carefully attended to, as I found these appliances at the machines in work, and as they respectively are, and were said to be at those at a standstill, most of the managers I came in contact with were well aware that they lost a considerable per-centage of the gold, and in some instances notable quantities of quicksilver besides. Considering this general loss, which in some establishments was occasionally much increased through an insufficient supply of, and the use of muddy water, I attribute it mainly to three causes, viz., the use of amalgamated copper plates, too strong an inclination and insufficient length of the blanket strakes, and last, though not least, to the introduction of mercury into the stamper boxes. It would lead too far here to enter into a discussion upon the merits or otherwise of copperplate tables generally suffice it to say that tables of the same pattern as those under notice were at one time in high favour in Victoria, but careful trials soon proved their inefficiency in many respects, and they have at all the principal crushing establishments been long ago discarded in favour of more perfect appliances which I shall mention further on. According to Küstel and other authori-

ties on the subject, they have also suffered a similar fate long since in California—the country where they were first introduced. The putting of quicksilver into the boxes is no doubt a great improvement in case of copperplates being used, but it is fundamentally detrimental in the crushing of stuff so highly charged with pyrites, as most of the Otago reefs produce. For it is a well-known fact that pyrites generally, though certain kinds more than others (and these abound in the latter reefs), cause a flouring of the mercury and amalgam in the boxes, and for the saving of such floured stuff no method has as yet been discovered. On this account I would therefore strongly advise to abandon the practice, even in case of copperplates being retained: for the loss both in quicksilver and gold caused by it alone is, perhaps, much larger than what would be sustained by less efficient working of the plates through its disuse. I may at this place take the opportunity to remark, that I hold the practice of special harm with regard to the cement crushing machines at Bluespur, on account of the abundant occurrence in the bottom portions of that cement of secondary pyrites, *i.e.* such formed in the drift, a kind that through easy decomposition is very prone strongly to flour the mercury. Considering also that the generality of the gold crushed from the cement is dirty, *i.e.*, more or less coated with oxyde of iron, or pyrites, and that, therefore, the copperplate tables (which I found only in use) have but a poor chance of retaining it, I think the attachment of blanket-strakes, or perhaps better of a well constructed tail-race, would be found very profitable. Touching the blanket-strakes, they are, at most machines, from ten to fourteen feet in length, and their inclination is seldom less than one and a half inches, and reaches two inches per foot—both figures which, considering that the supply of water is mostly rather copious, are certainly not calculated to ensure a satisfactory saving of the fine gold and amalgam escaping from the copperplates; irrespective of that, at some machines, the blankets are not, or have not been, washed frequently enough. Having herewith given my opinion on the point from whence at least the greater per-centage of the loss in gold and mercury proceeds, I would recommend the exchange of the present appliances and system for, or respectively their modification according to those for years successfully in use at the Port Phillip Company's works, Clunes—an establishment which in Victoria occupies the foremost place in satisfactory gold extraction, mainly because the practice there introduced of daily taking and assaying samples of the tailings serves not only for controlling and guiding the working of the appliances adopted, but in the case of any new invention in gold saving being tried, it affords also the best proof of the merits or otherwise of the latter. The system of appliances used at Clunes simply consists—starting from the battery—of three connected quicksilver troughs—the first with a 10-inch drop, the second with

System of Gold-saving Appliances, of the PORT PHILIP Coy. CLUNES.

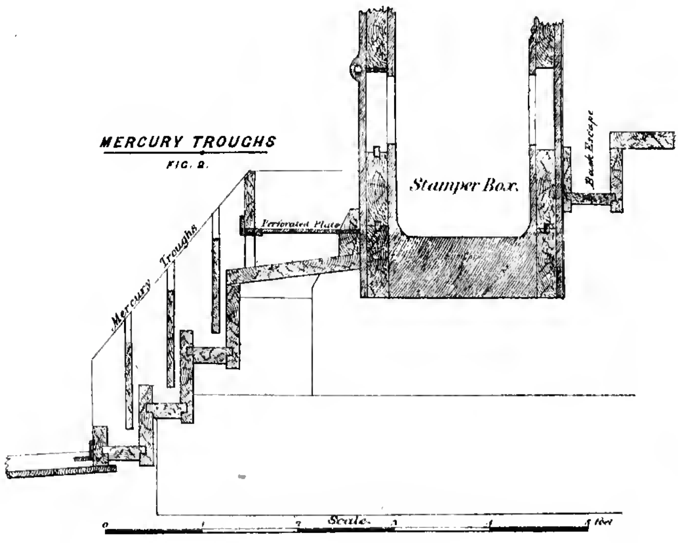
Longitudinal Section

Fig. 1.



MERCURY TROUGHS

FIG. 2.



a 9-inch, and the third, or lowest, with an 8-inch drop—through which the material passes in succession, to run next over 24 to 27 feet of blanket strakes, laid at a pitch of only one foot in 16, and ultimately to pass from the blankets through another quicksilver trough before it reaches the waste channel. This last trough is only cleared, however, at intervals of several months, whilst the upper troughs are cleared every week. In order to keep any coarse stuff from entering these latter, and also for even distribution of the material, a perforated plate is fixed right in front of the battery, through which both back and front discharge pass on to an apron which leads it (the material) into the first trough. An important part of each trough is the splash-board, which, reaching down to within about one and a half inches of the bottom (of the the trough), near to the surface of the quicksilver compels the material, in its drop, to pass more or less through the latter before rising over the lip of the trough. All the troughs are supplied with tap-holes on one side, by means of which the quicksilver and amalgam can be drawn off when required. The whole system will be easily understood by reference to appended Plate VIII., Fig. 1, which represents a longitudinal section, whilst Fig. 2 is a section of the troughs on a larger scale with the principal measurements marked. As to the blanket-strakes, their small inclination requires the supply of water to be up to eight gallons per stamp-head per minute, according to the nature of the stuff, in order to keep them free from sandy settlement. The rate at which the blankets are washed at Clunes is generally the upper row every hour, the second row every two hours, and of the remaining length of the strakes the blankets of the upper half every six, those of the lower half every twelve hours. Considering the nature of the stuff of the Otago reefs, I think, however, that partly because the more or less slimy stuff from the mullock reefs renders the surface of the blankets quickly inactive, partly on account of the great amount of pyrites contained in the quartz, a more frequent changing of the blankets than the above is advisable.

Touching the treatment of the blanket-sand, the method in use at most of the machines, viz., by revolving barrel and shaking table, gives, if properly carried out, the most satisfactory results, and deserves, therefore, general adoption. In the proper working of the barrel, upon which depends most, certain rules require to be followed, however, and as I had no opportunity of judging of the mode of operation at any of the machines, I give the following particulars on this head for comparison and guidance. Assuming the barrel to be about 4 feet long by 2 feet in diameter, it should be charged with 8 to 10 cwt. of damp sand, and 2 to 300lbs of mercury and set to revolve for about 8 hours at a speed of from 14 to 16 revolutions per minute. After this, it should be filled with hot water and set to revolve again for another 4 hours at the rate of 5

to 6 revolutions per minute, when the operation is finished, and the charge—quicksilver first—may be drawn off. Having been informed that at several of the machines the practice is followed of putting round stones or pieces of iron into the barrel, in order to grind the sand finer and aid the amalgamation of the gold, I have to remark that I consider this proceeding likely to prove more harmful than advantageous, on account of the large quantity of pyrites generally present in the sand, which through the grinding is very liable to sicken or flour the mercury and amalgam, and this invariably is followed by a loss of mercury and gold afterwards. A determination of the exact loss of mercury in this and the main gold-saving process by carefully weighing the metal at short intervals, is not practised, as far as I could glean, at any of the machines, but as it is of the greatest importance in testing the comparative efficiency of the amalgamating appliances, it ought certainly not to be neglected in future.

Having herewith noticed all the principal points touching the saving of gold from the crushed material, it remains to draw attention to the saving and treatment of the pyrites, which, as already mentioned, occurs in greater or less abundance in most of the quartz reefs of the Province. Although small experiments have as yet been made of the pyrites of but a few of the reefs, and trials on the large scale of that of only one reef (Southberg's Reef, Skipper's Creek) proving the payably auriferous character of the ore, still I think there can hardly be a doubt, judging from Victorian experience, that the pyrites of all the other auriferous reefs of the Province is more or less payably auriferous also, and it would be highly advisable, therefore, after the truth of this supposition has been established by fire assays*, to take early steps towards the con-

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* A good practical experiment for determining the quantity of gold in pyrites is the following: Weigh a good average sample of the dry ore—say about 2lbs—and roast it perfectly *sweet* (on a shovel over a fire will do), *i.e.*, till no more smell or arsenious and sulphurous acids is perceptible on stirring. Place the roasted mass into an iron mortar, mix it with so much water that it just packs or forms a *very stiff* paste, and add a tablespoonful of quicksilver. The mass has now to be rubbed with the pestle for so long till all the quicksilver has disappeared, *i.e.*, has been broken up into nearly microscopical particles, which are evenly distributed all throughout. A second similar amount of quicksilver may be worked through in the same way, and then hot water, a little soda, and a larger amount of quicksilver—about 5 or 6 tablespoonfuls—are added, and the mass gently stirred for some time, in order to allow the fine particles of the quicksilver to settle down and unite with the large lot at the bottom just put in. Now follows the careful washing away of the red oxyde of iron-slime in an enamelled iron dish, and ultimately the retorting—at not too strong heat—of the whole of the quicksilver collected. From the weight of the gold left behind—if any—the contents of gold per ton of the ore can of course easily be calculated. This experiment closely imitates the process to be adopted on the large scale, and, carefully executed, gives within 80 to over 90 per cent of the fire assay.

centration of and the extraction of the gold from the ore. Both these operations are not, however, very easy ones, but require, for profitable and satisfactory execution, much care, favorable natural conditions, and a considerable amount of capital in the construction of the necessary works. The saving operation has to be effected at each single crushing mill, and for it the so-called Borlase's buddle with Munday's patent scrapers, is the most approved in Victoria, but where capital and favourable conditions are wanting for the erection of these rather cumbrous machines, the use of a good length of blanket strakes—say 20 to 30 feet—and careful attention to, and more frequent washing of the blankets than hitherto practised, would at least save the greater quantity of the pyrites. With regard to the after treatment of the latter for the extraction of the gold, roasting furnaces and certain kinds of amalgamators are required, the working of which has to be specially learned. In fact, it may be said to constitute a special industry which not every company or reefowner might care or be able to enter into. In Victoria nearly all the larger companies have their own pyrites works, but there are also special private establishments of the kind, unconnected with crushing mills, at which miners or companies can either have their pyrites treated at a fixed rate per ton, or can sell it at a certain reduction on its gold-value, which latter is ascertained by careful metallurgical sample assay. A similar course must be left for private enterprise to follow in Otago.

In view of the fact that in the reefs of Victoria—and this as already stated, will most likely also happen in the reefs of Otago—the pyrites generally increases in quantity in depth, whilst the free gold correspondingly decreases, and that, moreover, the latter is the more difficult to save, the more pyrites the stuff contains: the pyrites question, as it is called, referring to the modes of concentration and after treatment of the ore, sanitary precautions connected with the roasting, etc., has there for years been one of increasing importance, and the Government appointed some time ago a commission to fully investigate the subject in all its bearings. The recently published report of this commission contains full information, with drawings of machinery, etc., on the best methods of pyrites concentration, and gold extraction; and as, if I entered upon a description of the respective processds, I should merely have to recount what is stated in it, I append a copy of this report instead. Considering, in conclusion, the general working effect of the crushing machines throughout the gold-fields of the Province, there are two serious natural disadvantages under which all suffer, though some in a stronger degree than others. I refer to the hard frost in winter, and the general low temperature of the water throughout the greater part of the year. The former compels the actual stoppage of the works for several months (five to six months at Skipper's Creek), the latter affects the liveliness of the quick-

silver, and thereby impairs, as it were, its amalgamating power. Against the first nothing can be done, and to ameliorate the second difficulty the introduction of hot water into the coffers can only conveniently be practised at those machines driven by steam engines. However, I think that, whilst the introduction of long blanket-strakes would prove a great safeguard against any loss of gold caused by imperfect amalgamation, the most rational way to meet the frost difficulty would be to have all parts of the machinery sound and in best working order, so as to guard against interruptions in crushing day and night through the summer months, in order to work up as well as the crushing material accumulated during winter stoppage, as also that concurrently produced.

Auriferous Drifts.

On this head I have only to record some observations that my time allowed me to make, whilst travelling between the different quartz-mining centres. Not having seen enough, therefore, to attempt any geological classification of the drifts, I will simply separate them into "newer" and "older," "upper" and "lower" drifts, as the case may be—main divisions, the existence of which everyone interested in the matter will easily recognise on visiting the Gold Fields.

Newer Drift.—Under this head belong all those extensive striking terrace formations of shingle and sand and a certain thickness, running from a few to perhaps over 100 feet of the flat stratum of similar material on which they rest, accumulated in those far-stretching, wide portions, of the present river-valleys, the original character of which as lake basins has long been recognised. The terrace formations of shingle, etc., resting on the rock of the ranges, fringing the valleys, the drift occurring in the smaller valleys or gullies between the ranges and the real river drift, are also here included. Besides the extensive sluicing operations which I saw executed in this drift along the banks of the Molyneux, Kawarau, and Shotover Rivers, the really grand scale on which hydraulic sluicing is carried on at Tinker's (Blue Duck Claim, Manager, Mr. J. Spratt), and Dry Bread diggings, excited most my admiration. To give an idea of the scale, I may mention that at Dry Bread, Greenbank and Company use 40 sluice heads of water with a mean vertical pressure of 130 feet, lessened about 25 feet through friction in the pipes, and have 4,500 feet of iron piping, besides an expensive stock of necessary appurtenances on the ground. Although the stuff washed is very poor, still the enormous quantity sluiced through in a short time, work being carried on day and night, renders the operation highly profitable. Work like this is entirely unknown in Victoria; perhaps the only other place in the world where it is practised being California. The thickness of the drift which rests on the so-called "Maori bottom" surpassed, in some places, 30 feet, and considering this in connection with the promis-

cuous way in which patches of it are worked along the foot of the Dunstan Range, though the generality are in front of, or near, the mouths of large permanent creek-valleys, one cannot help coming to the conclusion that the gold extends all along the foot of that range, the richer accumulations existing most probably in front of where the latter is most broken by rifts and gullies, whilst towards the centre of the wide valleys, it no doubt decreases in quantity, owing to causes to be explained further on. And the same chance I believe exists not only along the foot of the range on the opposite side of the wide valley, but also round the edges of all the other large old lake-basins. In fact, the resources of the Province of this kind of auriferous drift alone are practically inexhaustible, and their successful development only requires more of the enterprise and energy, as displayed by Greenbank and Company, in rendering the splendid water resources of the Province available for hydraulic sluicing. As some of the places which I consider very promising, and certainly deserving of the special attention of the drift miner, I may mention the part of the old Clutha lake-basin in the angle where the Bendigo Creek enters, and along the foot of the range on which the Bendigo Reefs occur. Also the extensive, so-called Miller's Flat, between Arrow and Queenstown, which, to all appearances, represents an old channel of the Shotover River, and should, as such, be very rich, judging from the splendid yields obtained from the river workings higher up. Mr. Warden Beetham first drew my attention to this dormant field, the high prospective mining value of which is believed in by many miners in the district. Another very promising area I take also to be the extension of Macrae's Flat towards the Taieri River.

Older Drift.—This comprises all those enormous deposits of harder gravel and cement called "false bottom," "Maori bottom" from its brown colour,—upon which the newer drift rests in the extensive old lake-basins of the Manuherikia, Upper Taieri, Clutha, and other river valleys. Also, the cement and gravel worked on the tops of the ranges between Milton and Havelock, that remarkable cement deposit of the Bluespur, near Lawrence, and the false bottom of Weatherstone and Waitahuna Flats, which three latter it must be borne in mind, represent also nothing else than lacustrine deposits, though small in surface extent, yet of comparatively great depth. The character and relation of all these deposits to the newer drift would at once suggest, to anyone acquainted with the gold fields of Victoria, the existence of runs or leads in their deepest parts or gutters; for, from the fact that they are all composed of the same kind of rock-material as the newer drift, there is no reason why they should not be equally auriferous. But yet, on comparing the relative conditions under which deposition of waterworn material takes place in lakes and watercourses—river and creek channels—which latter the Victorian deep leads unmistakably

represent, we find great differences; namely, whilst in a continuous watercourse, with evenly falling bottom, the current is steady onward, deposition takes place all along, and—leaving exceptions, caused by turns and local obstructions unconsidered,—the heaviest material settles in the deepest part, it is not so in a lake. There the current of the water of a river, or any smaller watercourse, one entering at one end, or any part round the circumference of the lake, gets suddenly checked either on account of the surface expanse or the depth, or both combined, of the stagnant mass of water, and the consequence is that the heaviest of the waterworn material (including, with regard to both the newer and older drifts, most of the gold), settles along the side of the lake-basin, whilst towards the centre of the latter, there is gradually less and finer material deposited. And this process goes on till the basin is ultimately filled up, though towards the other end or outlet of the lake, the deposited material will then consist of an increasing thickness of poor and light stuff at the bottom, and a thinning stratum of heavy one at the top. Of course the more inlets or sources of supply the lake has, the more they vary in strength, the more irregularly they are distributed around the margin of the lake, and the nearer its outlet, the more irregularity will be observed in the arrangement of heavy and light material towards the latter part and the centre. For these reasons, therefore, the old deposits of the lake-basins mentioned do not, in my opinion, contain deep leads in the true meaning of the term, but what I think very likely, is, that a certain width around the circumference of each deposit is auriferous and payably, or, perhaps, richly so in front and near the mouths of old, or of those present main-watercourses, which seem also to have been the sources of supply in olden times. And thus, these sites would, respecting the Manuherikia basin, for instance, conform with those of the present upper drift workings (Tinker's, Dry Bread, St. Bathan's, &c.) Touching the payable character of the drift, the fact that the top part, as far as tried, contains no or but small traces of gold seems to indicate that, as is the case with the older drifts of Victoria, the gold is concentrated—has settled—in one, or perhaps several, thin layers of washdirt. If it were generally dispersed from top to bottom, the drift would, except in case of great richness, not pay to work on account of the difficulty and expense. Only in cases of circumscribed basins, there would be chance, especially if the inflowing currents were strong and much charged with material, of coarse stuff, and gold being distributed all over the basins, though the heaviest stuff and richest gold would likewise be deposited partly on the inlet sides, partly on those rises on which the currents impinged; and, if these were steep, it would partly also slide down to the deepest parts of the basins. Of this feature, the Bluespur furnishes, in my opinion, a striking example. In a long, but very narrow basin, the gold might also

be carried by the current far down the centre, and if supplies came in at places down the sides, such a trough might prove auriferous for its whole or the greater part of its length, just according to the number and position of these supply channels. In this respect the valley of the Waipori (false bottom), offers, I think, by no means a bad chance. If anything deserves the term "lead," it would be the old drift-filled channels leading into or connecting two or more lake-basins, lying in the same line of drainage, or the end channels leading towards the sea. Of such leads, some have been wholly or partly removed by denudation—they once existed over our heads, as Mr. Vincent Pyke aptly remarked to me; for instance, that between the Bluespur and the false bottom of Weatherstone Flat, and part of the one that must have supplied the Bluespur from the north-west, both which, with the denudation of adjoining parts of the latter itself, respectively furnished the gold to Gabriel's and Munroe's Gullies. The cement deposit on top of the ranges between Milton and Havelock may also represent remnants of denudation of such a lead. However, I am convinced there are some channels of this kind yet existing, which it would be advisable to look for; for instance, two—one connecting the old drift-lakes of Weatherstones and Waitahuna Flats, and the other which fed the Bluespur from beyond Munroe's Gully. In fact, I think, there is even a likelihood of the existence of similar deposits as the Bluespur in that direction. From what I learned about the Cardrona workings, they certainly seem to represent a true old lead, and so does also a deposit, Mr. H. J. Cope kndly informed me of, namely a succession of cemented gravel-hills, commencing at the Eight-mile Diggings, Arrow River, at a height of at least 500 feet above Arrow, and dividing into two branches,—one terminating at Roaring Billy, the other at the Arrow River, about one mile from Arrowtown. This lead has in places been worked by adits, and found highly payable. In summing up my observations about the old drifts, I certainly think it not only very promising and advisable to prospect for the old channels between certain of the lake-basins mentioned, but also to test the false bottom of the lake-basins themselves at the places previously indicated. The cheapest and most convenient mode of effecting these trials would, no doubt, be by boring.

OTHER MINERALS.

Occurrences of Copper Ore, Grey Antimony, Cinnabar, and Brown Coal.

Copper Ore.—Of this ore, two occurrences were mentioned to me as worth inspection, viz.: at Waipori and Moke Creek. Learning, however, on further inquiry, that at neither place anything of the deposits could be seen on account of the workings, through having for years been neglected, being quite inaccessible, I did not think it advisable to spend the time in visiting the respective localities. I collected, however, from trustworthy sources, the following information about the two ore finds:—

Waipori.—According to Mr. Hill, the manager of the O. P. Q. Company, a large patch of cupriferous gossan was observed in the bed of the Reedy Creek, at a point about five miles south-west of Drummond's station. On working this patch, it led to a vein of yellow ore, one or two inches thick, running with the creek, east and west, and dipping north at one foot in eight feet. The prospector's sunk a hole to the north in the creek bank, about 20 feet deep, when they struck the ore vein on the underlay nearly 12 inches thick, and showing fine smooth walls. A flood soon after covered the workings in the creek several feet deep with mud, whilst the shaft fell in, and the place has not been touched since; but there is still a lot of the broken ore lying about on the creek bank. Assays of it have produced from 8 to 24 per cent. of copper. The rock in which it occurs is phyllite. As ores of this class, found within auriferous districts in Victoria, have on assay proved to contain at the rate of several ounces of gold per ton, I gave a specimen of the above ore to Professor J. G. Black, the Provincial Analyst, for assay, and he kindly sent me the following report:—

"This was a sample of copper ore—copper pyrites—averaging 12 per cent. of copper. It was examined for gold, and found to contain that metal *in very marked quantities*, though from the small weight of the sample sent—six ounces of ore—I was not able to make a quantitative determination. A larger quantity, say 20 lbs., of average quality should be sent for assay."

Considering the character and increasing thickness of the vein, and that the ore, according to the average of the assays made, might pay to work, if easily procurable in quantity, I think the vein derserves a further trial, more especially for determining its extent and behaviour in strike.

Moke Creek.—Mr. D. Maekellar, the secretary for the gold fields, who examined this place, could only find in the line of the old workings, situated close to the creek, thin seams of malachite and yellow ore interlaminated and small partieles impregnated in micha schist, whieh forms the rock formation of the locality. On the opposite side of the ereek a more lode-like looking formation, of 1-1½ feet thick, of gossan ore, erops out just a foot or two above the level of the water, dipping apparently downward in strike; the latter being N.W. and S.E., and the dip slightly S.W. Pieees of native eopper, several ounces in weight, have been found in the creek below the plaee. Aeeording to Mr. Bradshaw, of Dunedin, the old workings followed a lode of solid yellow ore, 3-5 feet thiek, of which assays by Dr. Hector and himself gave 22-24 per eent. of copper, whilst Mr. Haeket, who examined the lode on behalf of the Government, estimated it at 12 per eent. on the average. This ore, of whieh I saw a large lump, in Mr. Bradshaw's offiee, is also like that of Waipori—an intimate mixture of iron and copper pyrites, and contains likewise some gold, aeeording to the following report, kindly furnished to me by Professor J. G. Black, of an assay he made of a speeimen I gave him, viz.:—

"This was a sample of eopper pyrites, ranging from 5 per cent. to 19 per cent. of copper. It was examined for gold with *positive* results. The quantity analysed was too small, being only 13 ounees, to determine the per eentage of gold. The quantitative analysis showed that gold is present in very marked quantities. Another sample, 20 lbs. at least, should be sent for assay."

Taking into aceount the quality of the ore, and relying on the statements as to the thiekness of the lode left in the workings; as also, that limestone for flux and fire-clay oecur in elose vicinity, and fuel is not far off, I do not see why this lode should not pay for working, and it seems strange that it should have been—and for so long—negleeted.

Grey Antimony.—The two prineipal oeeurrenees of this ore I was told of, are—One about six miles N.W. of Waipori; the other on the top of the Carriek Range. Hearing on enquiry that the Waipori one is situated in a plaee so diffieult of access, that earriage expenses alone would nearly absorb the value of the ore at the ruling market prices, in faet, that it would never pay to work, exeept with railway aecommodation near at hand, I did not spend time in visiting it. The ore is said to oeeur, similarly as in Vietoria, in bunehes running in a lode-like way for a long distanee, some of the bunehes being 5 to 6 feet wide. Aeeording to specimens I saw, it is of a very fine quality, and should fetch the highest market price. There seems also to be a considerable quantity of yellow oxide of antimony (Cervantite) to be associated with the sulphide ore.

Buchan's Antimony Lode, Carrick Range.—This lies about $1\frac{1}{2}$ miles east from Carricktown, very nearly on top of one of the highest spurs of the Range, about 580 ft. above the nearest gully. It strikes E. 15° S., and dips northward at an angle of about 55°. Although only superficially opened in a few places, it is traceable for over a mile in length round the top of the range towards Carricktown, and also some distance down hill. Its thickness varies in the workings from 6 in. to 2 ft., and, as Mr Buchan, who kindly showed me over the ground, informed me, one block of solid ore was worked out weighing above 3 cwt. In parts of the lode exposed, the ore is, however, rather poor, being quartzose and mixed with impure oxide. As Mr Buchan found gold in the casing, I think there is, as in similar lodes in Victoria, every probability of the lode proving auriferous, wherever quartz makes its appearance in some quantity. It is very favourably situated for being opened in strike at great depth by an adit-level from the western slope of the mountain, and a short adit to prospect it, at 40 to 50 ft. in depth, could also easily be put in at right angles to its strike. A deep adit from the eastern side of the range, which, I understand, has been under consideration, would, I think, be both inadvisable and premature. For, although the lode is a promising one, the expense of carriage of the ore to the nearest market would be so high as to leave but a small, if any, margin for working expenses out of the price obtainable for it. Only in case of its proving payably auriferous, for which, I think, there is some chance, the putting in of a deep adit would be warranted, but then it should take place as just indicated from the western slope of the mountain in the line of strike of the lode.

Cinnabar.—A discovery of this valuable quicksilver ore in some quantity in the neighbourhood of Waipori was made known nearly eight years ago, but the place having been entirely neglected since, very few persons knew about it, and it was only after much loss of time that, from directions received, Mr. Hill, the manager of the O.P.Q. Co., who kindly acted as my guide, was able to find it. The site is a deep narrow gully about three miles south of Drummond's Station, in the centre of very broken country, at the foot of the Waitahuna Heights. The gully has been worked for gold, and the cinnabar, in small grains, and occasionally larger pieces about the size of a bean, was obtained in washing the stuff. The point which yielded most of it is near the head of the gully, and there some eight holes have been sunk in angular quartz and schist-drift up a depression in the bounding range. From these holes—now all collapsed—which apparently ranged from 8 to 16ft. in depth, samples of several pounds in weight are said to have been obtained. On closely searching the spoil heaps round the holes, I could not, however, discover any traces of the mineral. Reports say that the few men who worked at this spot could easily have

washed out 5dwt. of fine ore in a week; but, if such were the case, it seems strange that they should not have done so, as the value of hat quantity would have well repaid them for their trouble. As cinnabar, though in less quanity, has been found for miles around this place, in nearly every gully worked for gold, it may either, like the cinnabar of Mudgee, New South Wales, have been formed in the drift itself—a very rare occurence—or have been derived from the denudation of thin veins in the crystalline schist surrounding. And this latter origin I consider the most likely, judging from numerous occurrences of the kind in Europe. Very few of these, however, have, even with cheap labour and under other favourable conditions, proved payable to work; and I do, therefore, not think that the place under notice deserves to be further prospected, more especially as local circumstances would render this work, if properly executed, very expensive.

Brown Coal.—In consideraation of the high value the occurrence of this fuel is for the Province, I visited several of the mines within easy reach during my journey, and made the following observations:

Shag Point Coal Mine and neighbourhood, Palmerston.—This mine, situated within a few chains from the sea shore, is on a fine seam of first-class pitch coal (the best kind of brown coal) 7 to 10ft., in places 12ft. thick, which dips at the rate of about 1ft. in 10 N.E. towards the sea, and rises into the Shag Point hills at the back—the field available for working being indeed very large. It has been opened, and is being worked by a fine adit, and the system of exploitation adopted is by "post" and "stall," the stall being taken 14 to 16ft. wide, whilst the pillars left between are only 7 or 8ft., a thickness which appears to me rather small to insure the safety of the mine; for there is the danger of the front pillars being crushed long before the stalls have been wrought to the farthest end of the field. Below this fine seam, with a stratum of 4ft. of shale between, there is another seam of similar good coal about 4ft. thick, which has not as yet been worked. Walking along the beach this lower seam can be traced for a considerable distance to a point close to the mouth of the Shag River, where it disappears towards the sea in consequence of a roll or saddle in the strata, well exposed on the cliff, changing the dip to W. 25° N. at angles varying from 25° to 45°. Round the cliff, up the Shag River, which runs close at foot, a series of six seams crops out through a distance of 5 or 6 chains, and there may be several more higher up the valley towards Mount Puke Ivitai. Some of these seams are several feet in width, and their basset edges can clearly be seen across the river, disappearing underneath the sand hills of the flat beyond, their dip being at an angle of about 35° seaward. As there is a considerable breadth of ground between the shore line and the line of strike of the seams, from the river across the flat,

there is no doubt some chance of a certain extent of the seams existing and being workable in the lower end of the flat above high water mark. All depends upon the depth of the valley, respectively to the thickness of the overlying sand and drift deposits. If these latter are very shallow throughout, the coal ought to exist underneath the whole of the above area; whilst on the contrary, if their thickness is very great, there is little or no chance for it at all, for in that case the slope of the valley formed of the coal rocks would be correspondingly steep, and the seams would run down it towards the sea, probably without curving round into the flat, outside high water mark. Mr Rich, the enterprising proprietor of Bushy Park, who kindly conducted me over the ground, told me he intended to risk some money in prospecting for the seams in the flat by sinking and boring; and he may by this time have already solved the question as to their existence at a spot we agreed upon as the most suitable to commence operations. Whether the seams, if found, would pay to work, is a rather doubtful point, however, considering the large quantity of water that may likely exist in that part of the valley, representing, as it does, the embouchure of a pretty large river.

The Real Mackay Coal Mine and neighborhood, Tokomairiro.—This mine, kindly shown me by the fortunate proprietor, Mr. Mackay, is opened upon a splendid seam of pitch coal, about 21 feet in thickness, of nearly as good a quality as that of Shag Point mine. It (the seam) is solid and pure throughout, as far as exposed—a distance of about 2½ chains, and dips at an angle of 4-5° towards W. 20° N. The workings, consisting of an irregular quarry, are situated on the side of a low flat-topped hill, dividing two gullies, and of which the seam no doubt forms the base throughout, being overlaid by an increasing thickness of sand and fine clayey gravel. But even right on top of the hill this overburden would probably not exceed 20 feet in depth; at present it amounts to about 10 feet. The quantity of coal available for remarkably easy access is extraordinary, and if working were carried on more systematically, the working expenses per ton might be reduced to perhaps less than half of what they are at present. For instance, instead of throwing the overburden down the face on to the floor of the seam, and moving it from there once or twice over, as I saw being done, a tramway ought to be constructed from the top of the seam into the gully close in front, on which it could be at once trucked out of the way. In the breaking of the coal, more care should be exercised in order to produce a less quantity of smalls than at present; and a more advantageous method of working would be by side stopes, similar to the Long Wall system, with small tramroads leading from the stopes to filling places for carts, &c. As far as observable the seam extends into the hills all round the mine, but apparently becomes thinner and

dips steeper the further away from the latter. At one place, some five chains eastward, it has been sunk upon and found only about twelve feet thick, but of fine quality, with thin seams of jet running through it; whilst some 16 chains to the N.E., where it is plainly exposed up the side of a hill, it is reduced to about 6 feet, quality unaltered. A local company is here opening it, at a spot well chosen near the foot of the hill, by an adit at present 40 feet in length, and with the object of working the seam in the proper manner up its dip. But they had already worked out an apparently large portion of the seam in a very disadvantageous way down its dip, and at an unsuitable place some distance up, and in a sharp depression of the hill; for every bucket of coal and probably also of water, collected under foot, had here to be raised up the incline and the coal carted down the hill to the point, where the seam is now being—and should originally have been—opened. There are several other places on the flanks of the surrounding hills, where coal has been prospected and slightly worked; whether these are on the seam just noticed or on different seams, requires yet to be determined. Considering the extent, easy accessibility and quality of the coal already disclosed, irrespective of the chance of other seams existing, its neighborhood to the railway, &c., this locality may likely become one of the most important sources of supply of the fuel for the Province.

Brown Coal Mine, near Lawrence.—This lies about ½ mile west of south of the town, and the deposit—an earthy brown coal—seems to occupy a small trough or basin. For where opened its dip is a few degrees south of east at an angle of 15 to 20° ; but another outcrop, about ½ mile beyond, on much higher ground, dips in the reverse direction, thus proving a fall from both sides towards the centre. It was first opened by an incline, but is now worked by a fine roomy shaft and horsewhim. Its thickness is at present 17ft, and seems to increase towards the centre of the basin; but only 10 to 12ft. of the bottom part are taken, in order to secure a good roof of the remainder—very little timber being in this way required for support. Although the coal, as an earthy kind, is of but a middling quality being laminated and falling easily to pieces on exposure to the atmosphere, still, as it burns very fairly, giving out a good heat, it is of high importance to the district, and duly appreciated for household and other purposes. In some places in the deposit it is rich in resin, and its quality seems much to improve towards the centre of the basin. Judging from its general character, I think this coal would be well suited for being compressed into briquets. The deposit is overlaid by a stratum of fine fire clay, which is manufactured into first-class bricks at the mine.

There are several more deposits of brown coal of generally good average quality, worked higher up the country, for instance, between Roxburgh and Alexandra, at the foot of the Carrick Range,

between Cromwell and Arrow, in the valley of the Kawarau, etc. These I had no time to visit, and can only say that lying as they do within districts entirely bare of timber for fuel, their occurrence proves an inestimable boon to the inhabitants. Judging from their sites, as pointed out to me, I think there is every probability of numerous other deposits of the kind existing in the old lake basins in that part of the Province.

Down country, near the seaboard, the occurrence of some fine deposits of the fuel is hardly of less importance; for instance, of the Green Island, near Dunedin, and of Kaitangata, the coal of which latter, judging from specimens, would seem to rival that of Shag Point in quality.

In Bohemia, and some parts of Germany, more especially Westphalia, brown coal occurs in abundance, and it is consumed in immense quantities, not only for household purposes and common steam engines, but also, compressed into hard briquets, for locomotives, and even for gas-making. Regarding its use for steam engines, several inventions have there been made in the construction of fire-places for the boilers, which greatly enhance its heating effect, whilst being easily attended to, and not very expensive, and such an improvement in the mode of burning the fuel would be worth introduction, or certainly at least a trial in the Province, I attach a drawing of a fireplace of this kind—the so called "Treppen Rost" or "Step-furance"—most approved of in Germany, and give in appendix 13, full particulars regarding its construction and mode of working.

In herewith concluding this report, I beg to return my cordial thanks to Mr. Mackellar, the Secretary for the Gold Fields, for his urbanity, and the kind and valuable assistance he afforded me in my work during the time of our joint travel, and to state that I found on the part of all—whether engaged or interested in mining—with whom I came in contact, an earnest desire to further, in every way, the object of my visit. In the subsequent descriptions of the reefs, I have given the names of those who principally aided me in my examinations; whilst I beg here especially to acknowledge my indebtedness to Mr. L. O. Beal, Captain Hutton, and Mr. H. J. Cope, for much valuable information and advice they imparted to me on many subjects comprised within the scope of this report.

I have, &c.,

George H. F. Ulrich, F.G.S.,

Consulting Mining Geologist and Engineer.

LIST OF APPENDICES TO FOREGOING REPORT.

APPENDIX 1.

The Saddle Hill Reef, Green Island, near Dunedin.

This reef strikes E. 14° S., and dips northward at an angle of about 55° crossing the country—a soft phyllite—both in strike and dip, the walls pretty well defined. The workings being inaccessible, Mr. Eggers, a shareholder of the Company, and who worked the mine last on tribute, gave me the following particulars respecting their extent and nature and behaviour of the reef as far as opened. There are two vertical shafts on the ground which struck the reef on the underlay, one at 49 feet, the other at 125 feet in depth, whilst an inclined shaft, in the line of dip of the reef, runs from the surface to the bottom of the first vertical shaft. From between this shaft and the deep shaft, a considerable portion of the reef has been taken out, and at the bottom of the latter the workings extend 80 feet towards the east and 50 feet westward—the quantity of stone removed and crushed amounting, on the whole, to about 2,000 tons. There was not much water to contend with. The reef which has a ferruginous casing on the hanging, and a clay casing on the foot wall, consists of alternating blocks of good and hungry-looking quartz, and such of mullock, dipping westward in strike at a rather flat angle. It was from the surface down to 50 feet about 7 feet thick, but increased to 9 feet, and even 12 feet, in parts of

the lower workings. At the eastern face of these latter the good-looking quartz is only from 5 to 12 inches in thickness, the remainder being hungry-looking, but in parts rich in pyrites. At the western end there are 4 feet of good quartz on the foot wall, and 3 feet of a poor one on the hanging, with about 5 feet of mullock in the centre; good stone exists also for some distance under foot. As regards the auriferous quality of this good stone, it would yield about 14 dwts. per ton, but as it could not be specially selected, and a great deal of the poor stuff had to be taken, the average yield from the 2,000 tons crushed was only at the rate of 5 dwts. per ton. In its direction westward from the workings, the reef disappears under the alluvial of the flat, and is not traceable up to a point about half-a-mile distant, where a small outcrop again indicates its presence. Towards the east it is also hidden for a distance of about 5 chains, but there, close to the battery, it crops out again, showing a thickness of about 7 feet, whilst a shaft sunk about 24 feet northward, struck it on the underlay at a depth of 37 feet. It proved here to be about 4 feet thick, and the stone would, according to Mr. Eggers' estimate, pay about 7 dwts. of gold per ton; but none of it has, as yet, been crushed.

The crushing machine is erected about five chains from the workings, and consists of ten heads of revolving stamps of four or five cwts., in two batteries, driven by a steam engine with brown coal as fuel. One of the coffers is deep, the other shallow, and the stamps are fed by hand. The punched gratings have one hundred and twenty-two holes per square inch, but the holes are judiciously made considerably smaller than their usual size at this gauge, by the gratings being brought to red heat and hammered. As gold-saving appliances are used for one battery, an improved kind of amalgamated copper-plate table (three plates, each with a flat ripple in front, fixed step-like, the drop from one to the other being seven inches), succeeded by three blanket strakes of fourteen feet in length, fixed at a pitch of one inch per foot; for the other battery serve the common amalgamated plate-table, with shallow safety-ripples in front, from which the stuff passes over three blanket strakes, twelve feet long, and having the same inclination as the others. The blanket sand is treated in a small Berdan machine, from which it runs over a copper-plate strake. The crushing capability of the batteries is about sixty tons per week. Mr. Eggers was cognizant of a considerable loss of gold and floured mercury, on account of the large quantity of pyrites contained in the quartz. With 100 feet length of blanket strakes, he thought he could save about three tons of this ore during a week's crushing. An experiment which he made with a sample of 330lbs., by first roasting, and afterwards treating it in the Berdan machine, gave four pennyweights, or at the rate of about one and a-half ounces of gold per ton —a yield which, considering the imperfection of the trial (roasting

having not been carried on far enough, and the Berdan being not a good amalgamator for the purpose), must be regarded as very satisfactory. Looking at the character and prospects of the reef, I certainly think it ought to be profitable to work, *i.e.*, on a larger and more systematic scale, and with the gold-saving appliances improved.

There are three other strong and apparently well defined reefs occurring between the reef just described and the main road, a distance between a quarter and half a mile, in all of which gold has been found, and which it would therefore be advisable thoroughly to prospect. Of one, nearly eight feet thick, 50 tons were crushed by Mr. Eggers, and produced at the rate of two and a-half pennyweights per ton, though previous small trials had indicated a far better yield.

APPENDIX 2.

The Canada Reef and Bruce Company, Tokomairiro.

This reef, to which I was kindly conducted by Mr. Capstick, jun., of Tokomairiro, numbers amongst the strongest and best defined of the Province. Its strike is E. and W., and its dip north at 75° to 80°. It shows fine, smooth walls, with clay casings, and crosses the country both in strike and dip—the latter, a blue and greyish-blue, hard phyllite, striking E., 23° S., and dipping southward at 75° to 80°. The length the reef is traceable reaches perhaps a mile, and it has more or less extensively been worked at various places by adits, deep open cuttings, and shafts over a distance of nearly half a mile, the workings furthest west lying high on the steep mountain slope facing the north branch of the Tokomairiro River. At present it is worked about half a mile east of the river by a fine vertical main shaft, seven and a half by three and a half feet in the clear, arranged for ladders, double hoisting, and a six-inch drawing lift. This shaft, sunk close to the reef, is 80 feet deep, and a cross-cut from the bottom north struck the reef at ten feet. From this point a drive along the strike of the reef extends westward 180 feet, and eastward 550 feet, meeting at 400 feet a windlass shaft, from which stoping is being carried on towards the main shaft. As regards the nature of the reef, it consists of alternating blocks of good and hungry-looking quartz and mullock, dipping apparently eastward at a steep angle, and varying in thickness from two to seven feet. A small block of hungry, white, and glassy stone exists close east of the main shaft; but further on, fine seamy, ferruginous quartz appears in the eastern drive, and continues, though interrupted by occasional small bands of mullock, the whole distance to the windlass shaft. West of the main shaft the reef looks well, and carries much pyrites along to very near the end of the drive, where a block of mullock makes its appearance.

All the quartz passed through contains gold in very fine particles, but the blocks of the seamy, good-looking stone most, and there are in them also occasional narrow shoots, which, if taken out by themselves, would give very good returns. Such work, however, would amount to nothing else but robbing or picking the eyes out of the mine, and prove also the most expensive in the end, and Mr. Todd, the skilful mining manager, intends therefore, very properly, to work all out straight ahead. The quantity of stone available in this way on the eastern side alone will be very considerable, as by far the greater part of the backs between the level aad the surface is still standing, and the windlass shaft lies 50 feet higher than the main shaft. Touching the yields, they are rarely above 5 dwt. of gold per ton, and according to Mr. Driver, the legal manager of the company, the mine pays its way at less than, and leaves a profit at, that figure. From what I could learn about the character of the reef in the old workings towards the west, it was very similar as in those described—*i.e.*, blocks of quartz, alternated with such of mullock, and the former proved more or less auriferous. At one place, in fact, in an adit from the steep slope facing the Tokomairiro River, a patch of stone was found, yielding 5 oz. of gold per ton. The reef might on this side be opened by an adit from the river at a depth of perhaps 300 feet or over.

The crushing machinery consists of one battery of five heads of revolving stamps, driven by a fine turbine, which also works the hoisting gear and pumps for the shaft. The gauge of the gratings is 122 holes to the square inch, and the battery is supplied with a self-feeding hopper. The speed of the stampers is from 72 to 76 blows per minute, and the crushing capability of the battery 50 to 54 tons per week. As gold-saving appliances are used, two quicksilver troughs, with splash-board, and eight-inch fall each, and four lines of blanket-strakes of 15 feet in length, laid at an inclination of one foot in twelve. The blanket-sand, which contains a good deal of pyrites, is treated in the common revolving-barrel, and a dolly-tub and strake serve for collecting the quicksilver and amalgam. The aggregate of these appliances, which are carefully superintended by Mr. Todd, and work to his satisfaction, comes very near that of the Port Phillip Company, Clunes, previously recommended. On considering the character and extent of the reef, in connection with the fact that with good management so small a yield as 5 dwt. per ton, and from so small a quantity of stone as the small battery is able to caush, already leaves a profit, I think there can hardly be a doubt that this mine would become a steady dividend-paying one, if worked on a larger scale, and with increased crushing power; at any rate, as the turbine is strong enough to drive another five heads of stamps, these ought, at least, to be added. About six chains to the north of the reef just noticed, and running quite parallel with it, its strike being east and west, and the dip north at 75° to 80°, there is another reef, originally worked by the Table Hill Company, but

apparently for a long time neglected. This is also remarkably well defined, judging from the fine smooth walls exposed in the top part of the old workings, which extend for seven to eight chains in length. According to Mr. Todd, its thickness ranged in these workings, which are quite inaccessible, from two to seven feet, and its block structure, and the mode of occurrence of the gold, were quite the same as in the Canada Reef. The top portion paid in the average 5 to 6 dwts. of gold per ton, but in depth it became poorer, the stuff from about 150 feet down, where it was opened, but not much worked, by an adit from the northern face of the hill, yielding only about 2 to 3 dwt. per ton. This, in connection with considerable expense attached to the timbering of the workings, and more especially to the conveyance of the stone to the crushing machine, brought the mill to a standstill. However, if this latter expense were saved by the machine being shifted to the bottom of the hill, near the mouth of the adit, the prospects of the reef are still such as to warrant the hope of its paying renewed working. As regards the crushing machine, which lies by road nearly a mile away on the slope facing the Tokomairiro River, it consists of two fine batteries of five heads of revolving stamps each, driven by a splendid water-wheel of 39 feet in diameter—perhaps the largest in the Province. On account of the absence of a fly-wheel, the working of the batteries must, however, have been very unsteady. The gratings have 122 holes to the square inch, and the gold-saving appliances, with the exception of there being a spare blanket-strake (nine in all), are the same for each battery as in the previous case.

APPENDIX 3.

The Gabriel's Gully Reef, Lawrence.

Amongst the once celebrated reefs of the Province, this is perhaps one that most disappointed its original proprietors, though there are still some who believe in its being worth more than generally supposed, and who occasionally brave the dangerous character of the old working, by putting in prospecting drives at favoured places. I inspected what was accessible of the old workings, in company of Mr. Warden Carew and Mr. H. Squires, legal manager of the old Company, to whom I am indebted for all particulars concerning the character and behaviour of the reef, of which latter itself nothing could be seen. It lies at the head of a small gully running from the N.E. into Gabriel's Gully, and was discovered by a party working the alluvial at that place. The first workings, by open cuttings and shafts, extend for about 240 feet from the northern hill slope across the gully, a short distance up the opposite slope, and it was from them that the best returns were obtained. Afterwards, to ease the work, the reef was opened at 50ft. in depth, by an adit of 215 feet in length, starting lower down the

gully; and 120 feet below this again, a second adit, about 1200ft. in length, was driven for the purpose, both of opening it at that depth, and also to prospect for another reef supposed to exist beyond. This adit, which I inspected, proved unsuccessful in both points. It ought to have intersected the reef under notice at about 900 feet in, but only a thin, slightly auriferous casing was struck there, which, on being followed by a crosscut on the left of the adit, was found to bend flat and run out in the line of dip of a black carbonaceous bed, interlying common hard phyllite. Several small drives in different directions from the crosscut disclosed also no sign of the reef, but it was proved by a winze, sunk in the latter from the upper adit to the level of the lower one, which it strikes in the crosscut a few feet in, that the quartz runs completely out into the just mentioned casing, within about 20 feet above the crosscut, Judging from the surface workings, the reef strikes N. 15° E., and dips westward at 70-75°, crossing soft phyllite, striking N. 30° W.. and dipping westward at 30-35°. Its thickness ranged from a few inches to 12 feet in the upper adit workings, and the walls were very well defined, the hanging one showing a thin ferruginous casing. The gold occurred in a shoot extending from near the top of the northern hill (where the reef runs completely out into the hard phyllite) to the end of the workings on the south, and, though at first shallow, deepened rapidly in depth to about 53 feet down the winze, between the two adits. At the south the reef was found to be displaced by a slide, and on recovering it again about five feet out of its previous line, it soon became poorer, broke, and thinned out. The quartz containing the gold, *i.e.*, that within the shoot, was of a soft, ferruginous character, whilst below it a hard bluish stone came in, in which no gold could be seen. Except low down the winze, as above mentioned, and on the north and south in strike, this bad stone was nowhere lost underfoot in the upper adit workings. Regarding the yields, the stone from the shoot, though in places carrying at the rate of perhaps several ounces of gold per ton, paid in the average only 4 or 5 dwts. per ton; yet in spite of this low yield, the mine paid a handsome sum in dividends. The crushing machine of the Company, lately removed to the Blue Spur for crushing cement, stood at the lower end of the small gully, and consisted of two fine batteries of five heads of revolving stamps each, with common copper-plate tables, and blanket strakes attached—a turbine supplying the motive power.

In reviewing all the different points of Mr. Squires' information concerning the extent, lay, and character of the reef, I think there is a strong probability of the latter representing a large block which dips at a rather steep angle southward in strike, passing the lower adit over head, and lies therefore on its right hand side, not perhaps far off, where it would be advisable to search for it by a branch drive. For the hard blue quartz overhead, and likely to continue downward, and which owes its color mainly to a dense im-

pregnation of minute particles of pyrites, has not at all a bad chance of containing a payable shoot, judging from assays of specimens made for me by Mr. Morley, at the Melbourne Technological Museum laboratory, which gave at the rate of 14 dwts. of gold per ton.

APPENDIX 4.

The Otago Pioneer Quartz Mining Co.'s Reef, Waipori.

This reef, one of the richest, best developed, and most extensive in this Province, I inspected in company of Mr. E. Hill, the manager of the O. P. Q. Company, who kindly afforded me all the subsequent information about the yields and old and new workings, which were not accessible for examination. It strikes N. 25° W., and dips eastward at an angle of 56° cutting through hard, bluish grey phyllite, bearing about N.E., and dipping at angles varying between 15° and 30°. The walls are especially well defined, and show strong casings of tough blue clay. It has been opened, and in parts extensively worked, for a length of nearly two miles, and most likely extends considerably further both N. and S. The furthest point opened on the south by several shallow shafts in Thompson's claim, is at the edge of a wide flat which stretches towards the Waitahuna Heights. Here the reef is about 10 feet thick, shows well defined walls, and fine gold can easily be seen in the stone. Owing to the low position, there is a strong influx of water which will no doubt require powerful pumps to keep under. As I saw them, the water stood close up to the surface in these workings. Proceeding northward, the reef crosses and runs up the eastern side of a gully which was found rich in gold, having no doubt received its supply of the precious metal from the denudation of the reef. There are several old workings—adits and shafts—along this line, from which very good gold was obtained. These were stopped partly on account of the water, partly on account of the quartz running out into mullock in strike. Further north, about half a mile from Thompson's claim, we come to the site of operations of the old company, right at the foot of the range that divides this part of the country from the Waipori valley. A fine vertical mainshaft has here been sunk to a depth of 220 feet, about 40 short of striking the reef on the underlay, and by workings extending from it about 200 feet south and 100 feet north, the reef has more or less been taken out right to the surface. It (the reef) was 6-8 feet thick in the average, but in places it increased to 10 feet, and in others, near the main shaft, it decreased to 2 feet. It consisted of larger blocks of quartz divided by smaller blocks of mullock, dipping southward at 50-60°, but at the south end of the workings a large block of mullock, full of small quartz veins, was struck, which, as proved by an adit at the surface, extends south-

ward for nearly 200 feet. The quartz, especially from the lower parts of the workings, was very rich in pyrites. Touching the yields, they averaged from the upper part of the workings 7 dwts. of gold per ton, but lower down, where occasional rich patches were struck, they increased to 11 dwts., and throughout the workings south of the shaft, 12 dwts. per ton were obtained. Stone of pretty good quality was left nearly all along underfoot. The quartziferous mullock on the south end just noticed, would pay from 3-4 dwts. of gold per ton. There were formerly a crushing machine, hoisting gear and pumps, driven by a steam engine on the ground, but these have all been removed, and the mine deserted for a long time. Mr. Hill believes that a great deal of fine gold and amalgam were lost in the tailings. From these workings northwards up the range, the reef is not very plainly exposed, but right on the top it crops out three feet thick ; and there is a leader about 2 feet thick in the footwall, 8-10 feet distant, which dipping towards the reef will join it at about 20 feet in depth. Mr. Hill, who opened these outcrops by several small shafts, thinks the stone will pay from 6-7 dwts. of gold per ton. On following the line of the reef from these workings down the very broken slope of the range facing Waipori, a small adit is passed which has likewise struck the reef, but no more plain outcrops are met with beyond a distance of 150 yards. However, Mr. Hill, by intelligent prospecting, found it at several places, proving it to extend right to the foot of the range and underneath the alluvial of a gully near where this joins the Waipori Flat. And judging from the character and prospects of the reef, as disclosed at one of these places, the present company, which owns all the ground south across the range, beyond the old company's workings, has a fine chance of a prosperous future before it. This place lies in a narrow rift a good height up the range, about 400 yards from the top workings, and the reef, which is about 8 feet wide, and shows very well defined walls, with strong bluish clay casings. Near the surface there are only $1\frac{1}{2}$ to 2 feet of quartz on the footwall, the remainder being mullock; but towards the bottom this quartz thickens, while at the same time about 15 inches of quartz come in on the hanging wall—in fact, there is every indication of the mullock cutting soon out in depth. As regards the character of the quartz—of which a considerable quantity is taken out of the shaft—that from the footwall is seamy, rich in pyrites, and shows gold (some in coarse specks) freely, especially in the seams,—might pay several ounces to the ton ; whilst in that from the hanging-wall no gold could be seen, though it is also seamy and very rich in pyrites. On first exposing the reef, Mr. Hill washed eight ounces of gold from one tin-dishful of stuff, and obtained a number of specimens, rich in coarse gold, besides. At the other places opened by Mr. Hill, near the foot of the range, the reef is eight feet wide, and its walls are well defined, but it consists only of mullock, traversed by quartz-strings, which has shown but poor

indications of gold; yet it certainly deserves a trial crushing. The company have very judiciously, I think, adopted the plan proposed by Mr. Hill, namely, of opening the reef in strike by a large main adit, starting in the gully, right at the foot of a steep spur of the range—about 150 yards north of, and 100 feet below, the shaft in which the gold has been struck. According to Mr. Hill's rough traverses and estimates—for no proper survey, though highly desirable, has as yet been made of the line—this adit would strike the old workings at the southern side of the range, at a distance of about 1000 yards, and 100 feet below the bottom of the main shaft; whilst there might be about 400 feet of backs to rise upon towards the workings on top of the range, which lie about 550 yards distant.

The crushing machinery in course of erection within 800 feet of the mouth of the adit, with which it is connected by a tramway, consists of ten heads of revolving stamps in two batteries, with the common amalgamating tables and blanket-strakes—four for each battery—in front. I believe, however, that according to my recommendations, deep quicksilver troughs will be used instead of the amalgamating tables, or at least be interposed between them and the batteries. The motor for the batteries is to be a turbine, supplied with the necessary water at a vertical pressure of about 100 feet from a splendid race, which is cut twenty-two miles up the Waipori Valley, and capable of carrying twenty heads of water.

Having herewith given all the particulars I collected about this reef and the O. P. Q. Company's operations, I can only repeat what I have stated above, that the company have every chance of a prosperous future. Although the quartz occurs only in blocks, dipping most probably south in strike, still these are, no doubt, very large, and have afforded payable, and even rich, prospects; and it is not unlikely that the mullocky parts of the reef, or at least portions of them, might pay to work. The facilities for working are excellent, and I have no doubt it will soon pay the company to increase their plant by another ten heads of stamps, for the driving of which the turbine will have the necessary power. There is one point to which I would draw the company's special attention, and which Mr. Hill, their experienced manager, well understands, namely, to the great advisability of opening the first block of stone up well before commencing exploitation; and also, generally, of always keeping the adit going steadily ahead, in order to open up another block whilst that previously driven through is being worked out.

APPENDIX 5.

THE CONROY'S GULLY REEF, NEAR ALEXANDEA.

To this reef, which has been for a long time deserted, I was kindly conducted by Mr. Warden Simpson, Mr. Coleman, and Mr. R. Poole, of Clyde, who also afforded me all the particulars of its history. It strikes W. 23° N., and dips northward at an angle of near 80°, cutting very flat-bedded, nearly horizontal mica schist, strongly interlaminated with quartz. The walls appear well defined. According to the descriptions given, it averaged in the workings—now more or less fallen in—from six to eighteen inches in width, and consisted of quartz and mullock running side by side in strike, the latter frequently predominating. It has been opened and worked for over six chains in length, but is traceable for twelve to fifteen chains farther. The first workings consisted of small shafts and open cuttings, but afterwards, when some water was struck in the deepest shaft, an adit nearly 600 feet in length was driven in the strike of the reef from the slope towards Conroy's Gully, but starting so shallow that it required an open cutting over two chains in length, and nearly two more of a tramway, to obtain fall for the waste, and principally, that it lies only 50 feet beneath the surface at the end. In fact, when it reached so far, a great portion of the backs had already been worked out from the top. If on this account the adit must be pronounced, to say the least of it, a very injudicious piece of work, it appears still more so on considering that not far in advance of where the cutting begins the slope towards the bottom of the gully suddenly becomes very abrupt, and that it (the adit) might, therefore, have been put in from a point in the latter in the line of strike of the reef, lying at least 150 feet lower, and not perhaps more than 300 feet farther, than where it now commences. After all the backs above the adit had been worked out, a shaft was commenced in the reef at the far end of the adit, but after sinking ten feet, where water made its appearance, the work was given up, and the reef shortly after deserted. Down the shaft, and left in the bottom, a vein of quartz was followed of six to eight inches in thickness, showing a tendency to widen out, of which the last 25 tons crushed yield 1 oz. of gold per ton. Touching the aggregate of the returns, it amounted, according to Mr. Poole, to £2,005 from less than 500 tons crushed; whilst the total expenditure on the claim, including crushing machinery, tools, &c, was £3,756. The crushing machinery, which stood in the bottom of Conroy's Gully, close below the line of the reef, was sold to Williams and party, on the Carrick Range, who are there erecting it on a reef claim, to be noticed further on. All accounts agree that a considerable amount of the, in the average, very fine gold, as also of quicksilver, was lost in the tailings, through the crushing and gold saving process not being at all understood at the time. Comparing the great waste of money, through injudicious workings with

the total returns, and looking at the above indicated facility with which it could be opened at a good depth, whilst relying on information concerning its character as left underfoot at the end of the old adit, I certainly think this reef deserves another systematic trial.

APPENDIX 6.

Auriferous Reefs of the Bendigo District.

In my examination of most of the reefs of this extensive district, I was kindly accompanied by Mr. G. B. Douglas, the manager of the Bendigo Deep Level Company, and I am indebted to him for much of the information about the yields, workings, and other particulars, given in the following descriptions.

Logan's Reef and Cromwell Co.—This celebrated reef, in the possession of Messrs. Thomas Logan, B. R. Baird and G. W. Goodger, the latter of whom was kind enough to show us through the workings, is without question the richest and best defined in the Province, and has been very extensively worked for nearly half-a-mile in length, but is traceable for perhaps three-quarters of a mile further east in strike. It cuts through nearly horizontal, very quartziferous mica schist, at a strike of E. 5° S., dipping with slight bends for about 100 feet from the surface, close upon vertical, and then bearing gradually to the north, at an angle of 75°. Its walls are especially well defined and even, and there is a clayey ferruginous casing on either. According to Mr. J. Parry, the mining manager, its thickness in the present workings, ranged in places from two to six feet, but the average was about three feet. It did not, however, consist of quartz throughout, but there were larger and smaller mullock patches, the larger ones with a step-like outline at the top, of which some carried very good gold. The quartz shows a fine seamy structure, and is of a brownish colour and ferruginous near the surface, but in depth assumes a bluish colour, whilst becoming more and more strongly impregnated with pyrites, galena, and zinc blende (Black Jack). The gold occurs both in the seams and in the mass of the quartz, but was on the large scale not found evenly distributed through the reef, but to be accumulated in shoots dipping eastward in strike at rather sharp angles. Thus in places the quartz paid hardly a few dwts. of gold per ton, but was succeeded by such paying over two ounces, and this again by a shoot yielding up to and above six ounces per ton. The average yield from different working places, has for some time been over three ounces per ton. In the lowest part of these present workings, a few feet above the bottom of a whim shaft 260 feet in depth (there are two shafts, 170 feet and 114 feet deep, worked by derricks besides), one of the rich shoots paying up to six ounces per ton, has been struck, which dips at an apparently sharp angle eastward into the

so-called "Golden Link" ground, where the reef was first opened and most extensively and successfully worked. The deepest shaft on this line of workings, which have for some time been at a standstill, is 330 feet, and excellent gold (3 to 6 ounces per ton), from large quantities of stone, wrought either side, was obtained to about 150 feet in depth; below that the quartz became gradually poorer, and from near the bottom, where the water grew very troublesome, it paid only 7 dwts. per ton. There is every probability, however, that the rich shoot just noticed as existing at the bottom of the whim shaft, will be struck on further sinking. In parts of these workings the walls of the reef came close together, whilst in others they were up to 10 feet apart, both quartz and mullock, which filled these wide places, paying over 6 ounces per ton throughout. Towards the east the reef deteriorates very much in quality, and there are only a few places, one at about 4 chains and another at 2 to 3 chains still further on, where it has been superficially worked, and paid up to 16 dwts. per ton. Good looking leaders, running at acute angles towards the reef, have been struck here and there along the line worked, but none have been followed, and not a single prospecting crosscut has been driven throughout the whole extent of the workings. Whilst showing occasional outcrops, through the Golden Link ground, the reef came to a point in the line of the present workings, and whilst sending out two strong branches, one on the north the other on the south, it itself continues in the centre, but dips rather sharply in strike westwards as indicated by its disappearance down the pretty steep slope of the hill, on which the workings are situated. This feature has, however, only been properly understood lately. For whilst the workings on the main reef were carried on westward from the Golden Link ground, the northern one of the two branches—which soon assumes the same strike as the main reef, dips also close upon vertical, and shows a strong outcrop of massive quartz, in places 3 to 4 feet thick, down the slope of the hill just noted—was mistaken for its continuation, and worked for some distance eastward into the hill slope, *i.e.*, towards the other workings—and for about 130 feet in depth, paying in the average 16 dwts. per ton. The fact of its becoming poor and thin in the face at that depth whilst the workings on the main reef, but little in advance, showed the latter rich and strong, and appear to run gradually more S. out of the line, induced Mr. Parry, the manager, to drive a cross-cut south, which at 42ft struck the main reef, rich, and nearly 3ft. thick. From this point, which has been since connected with the main workings east, a drive is being carried on westward—the reef continuing of the same thickness and richness—and will soon extend beneath the gully at the foot of the hill. Touching the southern branch of the main reef, it is of a rather mullocky character, and also soon assumes the strike of the latter, with a nearly vertical dip—its thickness ranging from 9in. to 2ft. It has been worked up the slope and near the top of the

hill in several places—at one rather extensively—by open cuttings, but the returns were not very satisfactory. Still there is chance of its proving perhaps very rich near the foot of the hill, whence it is seen disappearing westward underneath the alluvial of the gully, at a point where it would be struck by a cross leader which has been worked up to within ½ chain on the south. This leader, which is from 3 to 6 inches thick, and runs rather crookedly towards it at a mean strike of N. 40° E., and dipping N.W. at 65-75°, has been worked for about ½ chain in length by a shallow open cutting,, and the quartz obtained is said to have been very rich. The mode of exploitation adopted for this mine is by underhand stoping—some of the steps or stopes being from 20 up to 40ft. high, and there were large places left open overhead, very unsafe for the men working underneath, and which ought therefore to be filled with waste to guard against accidents. As I have already given, at another place, my opinion on the comparative merits of overhand and underhand stoping, I need only remark here that I should certainly advise the owners of the mine to prosecute its future working in depth by the overhand system of exploitation. The crushing machine of the Cromwell Company (manager, Mr. Edward Rigg,) lies at the foot of the range near the mouth of the Bendigo Creek, about 1½ mile from the reef. It consists of 13 heads of revolving stamps in two batteries, fed by hand and driven by a waterwheel. The coffers are shallow, and the gratings have 122 holes per square inch ; formerly such with only 100 holes per square inch were used. As gold saving appliances serve common amalgamating tables, and 10ft. of blanket strakes, 4 for each battery, with an inclination of nearly 2 inches per foot. For the treatment of the blanket sand, serve a revolving barrel and shaking table. Owing to the large quantity of pyrites and other ores in the quartz, the saving of the gold is very difficult, and though Mr. Rigg carefully superintends the working, I feel convinced of both gold and quicksilver being lost in considerable quantities, and that it would pay well to treat the large heap of tailings accumulated near the battery. Before leaving this splendid mine, I may mention that the fortunate owners have very materially enhanced its value by the late purchase from the Aurora Company of a fine water race, capable of furnishing sufficient water power, not not only for working pumps and hoisting gear for a main shaft, but also for effecting crushing on a more extensive scale direct at the reef, and thereby saving the heavy expenses at present entailed by the carting of the quartz so far to the mill, over a difficult road.

The Reliance Company.—This Company, managed by Mr. J. Mitchinson, of Bendigo, to whom I am indebted for information about it and the district generally, holds the ground westward of the Cromwell Company, in the line of Logan's Reef, commencing at foot of the hill repeatedly mentioned in the foregoing description. Misled by the workings of the neighbouring company, before the

true position of the main reef was discovered, a fine whim-shaft was sunk to a depth of 170 feet on the line of the northern branch of Logan's Reef, close to the eastern boundary of the Company's lease, and right at foot of a high vertical precipice of mica schist. The upper 50 feet sunk through consist of drift, below that the reef branch was struck, but the quartz proved not payably auriferous, and also soon pinched out, the walls coming close together. There was water coming in at the bottom, but not very strong. When afterwards understanding how Logan's main reef really ran, the Company abandoned this shaft, and sunk another southward abreast in the supposed line round the foot of the high rock precipice; but this, according to a subsequent mining survey, seems to lie a few feet beyond the correct line. When I saw this shaft, it had penetrated to a depth of 100 feet, and, curiously enough, through nothing but small, angular, and washed drift from top down, whilst a very strong influx of water had made its appearance—features which, considering the vicinity of the rock, clearly indicate the existence at that place of a deep kind of pot-hole or gulch. As the water was too strong for further hand-bailing, Mr. Mitchinson intended to shift the whim from the other shaft to this one, and he may by this time already have ascertained whether, what seems not unlikely from the close neighbourhood of Logan's Reef, a deposit of rich washdirt exists at the bottom of the hole.

Regarding the chance of the existence of that reef in the ground, I think it is very good, judging from the strength of the reef in the nearest part of the Cromwell Company's workings; but touching the striking of it by the shaft, all depends upon its angle of dip westward in strike: for the steeper this is, the deeper will the shaft require to be sunk, though should it be flat, the reef might actually exist at the bottom of the gravel hole. The northern branch of the reef, on which the first shaft has been sunk, crops out on top of the precipice and is traceable for a good distance down the smooth western slope, where several old shafts from 50 to 75 feet in depth are said to have followed good quartz, whilst numerous auriferous specimens have been found along the line on the slope. Considering this, it would, no doubt, be advisable to prospect that reef-branch systematically along its line, and more extensively near that one of the old shafts, in which the best indications are said to have been obtained. The southern branch of the reef looks not at all unpromising, where it crops out at the foot of the hill, and would also, in my opinion, deserve to be well prospected.

The Aurora Reef.—This reef, which has been abandoned for the last two years, but from its really good prospects, certainly deserves another trial, runs about $\frac{1}{4}$ mile north of Logan's, at a strike of E. 5° N., and dipping northward at 75-80°. The only accessible portion of the old workings is an adit driven in the strike of the reef though in a rather irregular and crooked manner, a length of 700 feet, from a gully in which the crushing machine also stands, near by.

Similar to that on the Conroy's Gully Reef, this adit was also a very injudicious undertaking; for it lies only about 70 feet beneath the highest part of the hill into which it penetrates, and the greater portion of the reef had been worked out by shafts and open cuttings when it came to the end. Had it been continued about another 400 feet, there would have been a prospect of some 200 feet of backs to work up to a place at the surface, where in a superficial opening the reef was found 12 to 14 inches thick and paid, according to Mr. Douglas, 22 dwts. of gold per ton. In the adit, the reef was first struck on the left-hand side at 500 feet in, but the adit runs up to that point in such a manner—curving in and out—as to render it probable that along the whole or part of the above distance, the reef exists still undiscovered in the left hand wall—a supposition that might easily be proved by small cross-cuts. At the point of the adit, where it first appears, it is very thin, but very quickly increases to five feet in thickness, and a shaft sunk on it from the adit 58 feet deep, proved it to continue regularly downward, and to gradually widen to six feet at the bottom. Adjoining the shaft is a cutting 20 feet long and 15 feet deep, in which it is also left nearly five feet thick underfoot throughout. The quartz from both these workings paid from seven to nine dwts. of gold per ton; but as it is indeed very rich in mostly arsenical pyrites, and the gold saving appliances of the machine are of the usual imperfect kind, and were, as it is said, very badly superintended, I feel quite convinced that a great deal of gold and quicksilver was lost in the tailings. Beyond the just-mentioned cutting, the reef has not any more been prospected underfoot in the adit, but some distance further on it is seen five inches thick in the roof of the latter, and continues of that thickness right to the face, the hanging wall being especially well defined. Judging from this behaviour on the whole, I strongly suppose that the stone followed in the shaft and cutting represents a good and strong shoot, which dips at a rather sharp angle eastward in strike. As regards the old workings, they extend for a length of 280 feet, and the reef has been taken out right to the adit. The stone was there of a very ferruginous character, and ranged in thickness from one to five feet —average, about $2\frac{1}{2}$ feet. Extremely rich patches of golden quartz were found in places, and some of the crushings produced 2 oz. 16 dwt. of gold per ton; the average yields varied, however, from 16 dwts. to 1 oz. per ton. At the eastern end of the workings the reef splits into two branches, and a tributors' party, who worked there last, followed the northern branch for some distance, and realised from 8 to 13 dwt. of gold per ton. Further east, on the opposite rise of a little gully, intersecting the line of the reef, they sunk two shafts—one about 75 feet in depth—for prospecting the branch, but, strangely enough, though the line of the latter across the gully is clearly apparent, neither of the shafts lies on it, but one too far north, the other south, and a cross-cut between the

two has still good chance of discovering it. Some five or six chains further along the line from this point are the last workings of the tributors, consisting of several shafts ranging up to 60 feet in depth, from which the yields varied from 8 to 12 dwt. of gold per ton. Beyond these, there are no workings on the same line for a distance of over a quarter of a mile, where we come to those of the Victoria Company—an open cutting—from which 38 tons of stone were raised that produced at the rate of 14 dwts. of gold per ton. This yield of gold being too low to pay for working, carting, and crushing combined, the place was deserted. Touching the southern branch of the reef, it has been superficially prospected in several places for over a quarter of a mile in length, and proved to be auriferous, but not payably so. The, through long neglect, somewhat dilapidated crushing machinery of the old Aurora Company consists of two batteries of five heads of revolving stamps each, driven by a waterwheel; common amalgamated copperplate tables and blanket strakes 14 feet in length, lying at a pitch of nearly two inches per foot. Small remnants of blanket sand near the tail-race proved, on examination, to be rich in finely divided quicksilver and amalgam.

The Lucknow Reef and Company.—The strike of this reef is nearly E. and W., its dip close upon vertical, and the walls are well defined. It has been opened along the surface for about 300 feet in length, the main workings lying on top of a spur, which it crosses at nearly right angles. As these workings were inacessible, Mr. Chas. Colclough, the original discoverer of the reef and present legal manager of the Company, kindly afforded me information about them, and gave me other particulars concerning the reef. The latter has been worked out to depths ranging from a few feet to sixty feet, and yielded from 8 dwts. to over 3 ozs. of gold per ton. In the main shaft the reef, which proved about one foot thick, was followed vertically down to a depth of about 100 feet, but there a body of stone made its appearance, rich in gold and arsenical pyrites, and showing a thickness of three feet, *i.e.*, one foot of quartz on either wall, and one foot of mullock in the centre, and which was found to dip flat southward. The shaft was, therefore, turned on the underlay of this body, which was supposed to represent the main reef, and for a length of 14 feet followed it down to a depth of about 146 feet, where water was met with. A crushing from this underlay portion greatly disappointed, however, all expectations, for instead of several ounces, it paid only from 8 to 11 dwts. of gold per ton. As it was thought that the water would give too much trouble in further sinking, and also in order to provide an easy road for the stuff to the machinery standing in the gully at the foot of the spur, an adit was at once projected and started from near the machine without considering that the length it would have to be driven through hard, nearly horizontal, mica schist to strike the reef, and consequently its large expense was

greatly disproportionate to the small height of backs, estimated at hardly 40 feet, to be rendered available by it; irrespective of that, in which most opinions agree, closer examination would have shown that the water in the shaft was mostly due to surface percolation, and might have been easily beaten by a horse whim. At the time of my visit this adit, which makes two strong angles in direction, had progressed to a point which Mr. Besanko, the mining manager, considered from rough measurements—(the want of a proper mining survey and working plans is here painfully apparent)—to lie south abreast, or already a little beyond, beneath the bottom of the previously mentioned shaft—the last one hundred feet having, at the rate of £8 or £10 per foot, been driven E. in the line of a flat slide which he took from its position to represent the continuation of the flat reef left in the shaft; and in this supposition he seemed to all appearances to be correct. But if so—considering that only a few small pockets of rich gold-bearing quartz had been met with in the slide along the whole distance, and that moreover but a comparatively small stream of water had made its appearance in the face, though there were nearly 60 feet of water standing in the shaft above—the prospects of the flat reef at that depth appeared to me to be far from cheering. On the supposition of its forming a block dipping from the shaft eastward in strike, there was no doubt still of the chance of its being found of some thickness further ahead; however, in looking at the uncertainty and the expense or farther work, I advised the manager to discontinue driving on the slide altogether, and instead to open out eastward on a quartz reef, 9 inches thick and dipping vertical, which crosses the adit E. and W. some distance from its mouth, and in which gold is said to have been found when penetrated. In fact, there can hardly be a doubt that this reef represents the continuation of the main reef worked at the surface; for besides having the same strike and dip, its position in the adit—as ascertained by tape measurement—agrees tolerably well with that of the main reef, as given on a plan prepared by Mr. Evans, mining engineer, on which also a good length of the adit is marked. As regards the prospects of the proposed workings, I think they are very fair, judging from the character of the reef at the surface, and that gold has already been found in the portion crossing the adit; but it must not be forgotten that, as soon as the available backs are worked out, opening of the reef in depth will have to be effected by shaft and requires pumping and hoisting machinery. The flat reef may either be a so-called "dropper," or represent a reef parallel in strike to the main reef, which, on crossing the latter in depth, shifted it a little southward; still, whatever its nature, I take it to be uncertain in extent and auriferous character. The portion left in the shaft might perhaps be easiest opened from a rise from the end of the adit. Touching the crushing machine of the Company, it consists of five heads of

revolving stamps, driven by a turbine, copper-plate table and blanket-strakes; a rippled tailing-race forming not a bad addition.

Golden Crown Reef.—This is apparently a continuation of Logan's Reef, from which it lies about 1½ mile distant to the east. The discoverers, J. Wrightson and Co., have not done much work on it as yet; but from what is disclosed, it seems to be of a mullocky character, and from 9 to 16 inches thick. A crushing of 17 tons yielded about 8 dwts. of gold per ton.

Claim No. 10.—This lies also in the line of. and about 2 miles distant from, Logan's Reef. It contains a well-defined quartz reef, from 2 to 4 feet wide, in which superficial prospecting has not disclosed any gold as yet; but near to this reef, on the south, and dipping towards it, runs a parallel leader from 6 to 10 inches thick, from which a crushing of 26 tons produced at the rate of 26 dwts. of gold per ton. The reef deserves, in my opinion, to be properly prospected.

The Bendigo Deep Level Company, managed by Mr. G. B. Douglas. This is a spirited and, in my opinion, highly promising prospecting enterprise. The adit, which at the time of my visit was only 10-12 feet in, starts from the Bendigo Creek, southward, into the high precipitous mountain side, in a direction nearly at right angles to several reefs presently to be mentioned, and also to the lines of the main reefs previously described, though at more or less considerable distances east of their workings. Thus, according to Mr. Douglas's survey, it would intersect, at 60 feet in and 100 feet beneath the surface, the line of a reef 1 foot wide, which has proved auriferous; at 163 feet in and 300 feet below the surface, the line of the *Guano Reef*, a well formed reef, 2 feet wide, opened right above the line of the adit, and which has yielded from 15 to 26 dwts. of gold per ton from 5 crushings that ranged from 26 to 48 tons each. Next comes at 260 feet in and 450 feet beneath the surface workings, the line of *Broadfoot's Reef*, also a tolerably well-defined reef of 2 feet in thickness, from which 3 crushings of from 28 to 42 tons each, gave at the rate of 12½ to 14½ dwts. of gold per ton. Beyond this reef, at 400 to 500 feet in and about 500 feet beneath the surface, come two leaders, or small reefs, from which crushings have yielded 7½ to 9 dwts. of gold per ton. The line of the Lucknow Reef would be intersected at 700 feet in and 550 feet beneath the surface; that of the Aurora Reef at 1,400 feet in, and 700 feet beneath, and that of Logan's Reef at 1,900 feet in and 1,000 feet below the surface; also two leaders, each about 12 inches wide—one between the Lucknow and Aurora, the other between the latter and Logan's Reef—of which crushings yielded respectively 9 dwts. and 13 dwts. of gold per ton. A great collateral advantage the site of the adit has, is that from the Bendigo Creek running past its mouth a never-failing supply of water could be procured for crushing purposes, motive power included. The adit has been commenced only wide enough for single tramway, though

I think double tramway-width would have been far more advisable. What I would especially recommend to the company is to start as soon as possible work with a good boring machine driven by compressed air, which would save special ventilation of the adit, and to use gun cotton, or better still, Nobel's Dynamite, for blasting.

The Alta Reef.—This reef has been deserted for a long time, though its prospects seemed encouraging enough up to the last for an extended trial. It lies about three miles E.N.E. of Logan's mine, and seems, from what could be seen in some of the old workings, to run in a rather crooked way, at a mean strike of E. 3° to 5° W., and to dip nearly vertical. Walls apparently not very well defined. Its thickness seems to have ranged from 2 feet to 6 to 8 feet in places. Eight crushings realised at the rate of from $3\frac{1}{2}$ to 19 dwts. of gold per ton.

A peculiar feature in the reef was the occurrence on the south wall of masses of a very heavy, yellowish-white mineral, which proved very troublesome during crushing; and on examination of the spoil heaps from the workings, I discovered specimens and recognised it as "scheelite," or tungstate of lime. As this is a mineral that most frequently accompanies bismuth ores, there might be a chance of the reef carrying these ores in depth, or of their occurring in the immediate vicinity. The reef has not very judiciously been opened by two adits of 90 and 140 feet in length, and at the respective depths of 64 and 80 feet, whilst, according to Mr. Douglas, an adit from the opposite side of the range, where the machinery stands, would at a length of about 680 feet have struck it at a depth of 280 feet, and crossed besides four other reefs, of which one yielded 14 dwts. of gold per ton, from a trial crushing of 12 tons.

The crushing machine, connected by a long tramway and shoot with the mine, consists of ten heads of revolving stamps, in two batteries, driven by turbine; amalgamating tables of the usual pattern, and blanket strakes. Not being housed in, it is suffering much from exposure to the weather.

The Rise and Shine Reef.—This peculiar occurrence of auriferous stone—for it cannot be called a reef—lies about three-quarters of a mile east of the Alta machine. Judging from three small shafts, the only workings as yet executed—one 18 feet deep lying in the bottom of a gully, the other two shallower, sunk several chains apart on the slope of the southern range—it consists of a zone of highly mineralised mica schist of considerable width, and apparently striking N. and S.; dip uncertain. The stone worked out of the gully shaft, amounting to about 30 tons, is densely traversed with quartz veins in all directions, in which fine gold can freely be seen; and there is besides a considerable quantity of iron and arsenical pyrites present. Good prospects of fine gold can also

be washed out of a streak of loose stuff, resembling a casing, on one side of the shaft, whilst the fact that from below the line of the formation down the gully, and on the slope of the range, the alluvial drift has furnished rich returns of angular or not waterworn gold, is a clear proof of the richly auriferous character of the portion of the outcrop removed by the denudation. In reviewing all these different points, I think that the proper opening and working of this singular formation—which may likely represent a so-called "blow" leading to a defined lode in depth—would be a very profitable undertaking, more especially as there is a fine water-race near at hand to furnish the necessary supply of water, motive power included, for crushing purposes. If found to extend from the gully into the southern bounding range, it could there be opened and worked by an adit, lying at a vertical depth of perhaps near 440 feet below the top of the range.

APPENDIX 7.

Auriferous Reefs and Companies of the Carrick Range.

Besides the managers of the mines subsequently mentioned, the gentlemen who kindly afforded me informatian about the reefs were were—Mr. James Marshall, Mr. Charles Colclough, Mr. William Grant, and Mr. James Stuart. Progressing upward from the foot of the range, the reefs I visited are :—

New Royal Standard Company's Reef.—This strikes N. 20° W., and dips easterly at an angle of about 75°, but runs very irregular and is not well defined. It cuts apparently through the disturbed looking country rock—a rather soft phyllite—both in strike and dip. In parts of the old workings, which consisted of an open cutting, and irregular short drives, extending over several chains in length, it was formed of nothing but leaders of quartziferous mullock, for 15 or 16 feet in width, which yielded on crushing from 6 to 12 dwts. of gold per ton. Several small crushings from narrow places produced, however, up to 2 ozs. per ton. As it may likely become more defined and perhaps richer in depth, it would be advisable to prospect it by an adit from the steep slope of the spur which it crosses.

Crown and Cross Claim.—This is owned by Watson, Herbert and Co. The reef (worked by a shaft 47 feet deep, which will soon be in connection with an adit, driven from the bottom of the adjoining gully), strikes N. 20° W. with an easterly underlay at 75-80°, cutting through much disturbed phyllite, and ranges in thicknes, from 6 inches to 3 feet, and 4 feet in bunches. Its hanging wall is defined and smooth, the foot wall rather uneven. It consists of quartziferous mullock, traversed by occasional small quartz veins with gold fairly distributed throughout. 200 tons crushed paid at the rate of about 1 oz. per ton. The prospects under foot and in strike South are very encouraging—a prospect of the mullock from

the bottom, washed in my presence, gave a fair quantity of very fine gold, besides several small quartz specimens. At the northern end of the workings which—small prospecting shafts included—extend about three chains along the reef, the latter was found faulted 10 feet eastward by a clay slide 15 feet in thickness. In a small claim, next adjoining the Crown and Cross on the south, owned by Robert Scott and John Meyers, the reef was just struck by a small adit, during the presence of our party on the ground

This reef is considered to be the continuation of the "White Horse" or "Try Again" Reef, next to be mentioned; but as it runs some distance—about $1\frac{1}{2}$ chains—sideways of the latter, this can only be the case on its representing a faulted portion of it—a supposition not unlikely to prove correct, judging from the identity in strike, dip, and character of the two reefs, and the frequency of faults in the district.

White Horse or Try Again Reef.—Worked by Saltoun, Campbell, McKersie, and Co. This reef strikes N. 20° W. and dips eastward at an angle of about 76°, cutting through alternating harder and softer beds of phyllite—a feature which renders its course rather irregular: strong turns, both in strike and dip, being very frequent. The walls are in places well, in others badly defined; where well defined, they mostly show polished and striated casings. Its thickness ranges from 9 inches to over 4 feet, and it consists of quartziferous mullock, traversed by broken quartz veins, generally rich in arsenical pyrites, and sometimes pretty thick. carrying good gold, though the latter occurs also finely impregnated throughout the mullock mass.

Touching the occurrence of the gold on the large scale, it seems to be accumulated in shoots, which have a decided dip in strike southward. The average yield of gold has hitherto been about 1 oz. per ton from several hundred tons crushed, and there is no sign of the reef becoming poorer under foot. The main workings consist of an adit, extending about three hundred feet along the reef, from which stoping is being extensively carried on—the height of backs available up to the crown of the hill, amounting to nearly 100 feet. Another adit could be put in in the strike of the reef over 100 feet lower down the slope of the range; and this work it would be wise soon to enter upon.

Caledonian Company.—Managed by Mr. G. T. Stephenson.—This company is at present engaged in driving from the bottom of a deep gully an adit, which is intended to open the Caledonian Reef 180-200 feet beneath the level of the first adit, in which work has been stopped, on account of what was considered payable of the available backs—about 70 feet high—having been worked out, According to the direction of this upper adit, which followed the eef southward a length of 400 feet, the latter runs in a wavy line at a mean strike of S. 30-35° W., whilst several shafts sunk on it

from the adit show it to dip very close upon vertical. Its walls seem very well defined, and show thin clay easings. Touching the behaviour of the reef in the old workings, yields, &c., Mr. Stephenson kindly afforded me the following information:—"The reef ranged in thickness from 1-7 feet, but was in places pinched to a mere easing; and there were also shelves of hard rock, which frequently altered its course in dip, throwing it, step-like, several feet eastward. At the end of adit it runs thin, but still looks promising enough to induce a party of miners to drive a deep adit from the opposite slope of the spur, for the purpose of opening it in depth beyond the company's ground. Above the stopes, towards the surface of the spur, a considerable extent of ground is still unproved. The reef was of a mullocky character, but contained frequently broken veins and bunches of quartz, richer in gold than the rest. There have been close upon 800 tons crushed, at an average yield of about 1 oz. of gold per ton. Along and from the adit five shafts have been sunk on the reef, ranging from 12 to 100 feet in depth, in all of which it (the reef) has proved to be auriferous, though, with the exception of one, not so rich as in the old workings. In the two deepest ones (70 feet and 100 feet) the reef was rather irregular towards the bottom. Outside the adit there is a sixth shaft of 80 feet in depth, in which the reef has also proved not unpromising. The new deep adit, which is about 170 feet in, is driven in the direction of this latter shaft, and will soon reach the reef, provided the latter has not suffered any change in strike and dip. Considering, however, the frequent occurrences of this kind, viz., the eastward jumps in the worked-out ground, it must be apprehended that they exist likewise in depth, and it would therefore have been wise to cross-cut eastward for the reef before proceeding much farther with the adit. Mr. Stephenson is very sanguine of the reef proving payable down to the level of the latter, and, if so, looking at the height of available backs to rise upon, the company would be in a prosperous condition for a considerable time to come.

Proposed Long Tunnel Company.—On the high spur—the "Long Ridge"—between two branches of Smith's Creek, west, opposite the Caledonian Company's mine, a number of small mullock reefs have been superficially worked. One of these, the so-called "*Border Chief Reef*," strikes, according to Mr. Buchan, E.S.E., and dips northward at an angle of about 20°; thickness, about 6 inches; country very hard. A small patch of stone found just under the grass would have gone 30 ozs. of gold per ton, but it was mixed with a lot of mullock, and averaged on crushing only 6 ozs. per ton. The patch was small, and wedged out about 20 feet from the surface. The topographical features being very favourable, a company is projected, so Mr. Colclough informed me, for driving a deep adit from the bottom of the spur, to test this and the

other reefs, including the Caledonian Reef in depth, perhaps at 5 to 600 feet, and also to extend it towards the group of rich reefs, lying at more than 1000 yards horizontal distance, and about 1000 feet higher up the range; the stretch of ground intermediate, though no reefs as yet have been discovered in it, presenting also rather favourable indications of their existence. All I can say about this expensive project is, that it is a legitimate one, but it seems considerably more risky than the Bendigo Deep Level, irrespective of its not having the the advantages of the latter—touching a ready snpply of water for crushing purposes.

The Star of the East Company—Managed by Mr. Arch. Cameron. The Star of the East Reef strikes E. 20 to 25° S., and dips northward at 50 to 56°. It was opened by an adit in strike of 480 feet, which rendered a height of 108 feet of backs available beneath the top of the hill, into which the adit penetrates. These backs have been worked out for 250 feet in length to near the boundary of the Company's ground, whilst also a large portion of the reef has been removed from underfoot, between two shafts, 60 feet apart and 60 feet deep on the underlay, which workings produced about 1200 tons of crushing stuff—all quartziferous mullock—which yielded in the average 12 dwts. of gold per ton, the reef becoming more solid and improving in depth. In the backs the reef ranged in thickness from 2 to 8 feet, average 4 feet, and paid 14 dwts. per ton. As its further working underfoot from the upper adit proved too expensive, the company started a deeper adit from the other slope of the range, at nearly right angles towards the reef. This adit had at the time of my visit advanced a length of 440 feet, and Mr. Cameron expected to strike the reef at another 40 to 50 feet, provided it preserved the same underlay as where last worked underfoot from the upper adit. The height of backs to rise to these old workings would be about 250 feet. At a distance of 386 feet from the adit mouth the Company had, however, the luck of intersecting a new mullock reef, which proved payably auriferous, and was at once opened up, and has been extensively and properly worked since. A main drive along its strike is 230 feet in length, and the stopes extend on the west side of the adit for about 70 feet in length, and 10 feet in height, on the east side respectively 60 feet and 80 feet, and prospecting rises are opened some 80 feet higher either side. The height of backs still available for stoping is estimated at 250 feet. Two prospecting winzes, 30 feet apart, have also been sunk from the drive on the underlay of the reef—one 40 feet deep, on the east, the other, 60 feet deep, on the west side of the adit. The reef strikes, according to these workings, E. 15° to 20° S., and dips northward at an angle of 50° to 56°, a course nearly parallel to that of the oid reef. It was found to range from a mere string to, in places, over 3 feet in thickness, the mean being about 2 feet. It twists and turns, in strike and dip, in places, in a most perplexing

manner, and Mr. Cameron deserves great credit for having persevered and succeeded in following it in its tortuous course. The average yield of the crushings has hitherto been 28 dwts of gold per ton, and there is at present no apprehension of a falling off. Both in strike—at the two faces of the main drive—and in dip—in the winzes underfoot; the thickness of the reef was, however, below the average. As far as Mr Cameron has observed, the best paying stuff dips at a rather sharp angle in strike eastward. Of further particulars about this reef, I learned that its existence was long ago surmised, and it was originally searched for by the Black Horse Company, by two deep shafts, sunk in a mullock slide on top of the range, in about the line of the present adit, and which would have struck it, if continued not many feet deeper. There is a possibility, though by no means a strong one, of this reef and the old reef being identical, *i.e.*, that the latter represents a faulted portion of the former, in which case it would of course be found suddenly cut off in depth. The deep adit will, for the sake of the company I hope, soon dispel any apprehensions in this respect, by striking it at the calculated distance. As regards the crushing machine of which this company and the Heart of Oak Company, next adjoining, are co-proprietors, it is managed by Mr. W. Menzies, and consists of ten heads of revolving stamps in two batteries, driven by a steam engine—brown coal serving as fuel. Hot water is introduced into the stamper boxes. As gold-saving appliances, are used amalgamating tables and blanket strakes of 14 feet in length, laid at an inclination of 1½ inch per foot. The blanket sand is treated in the barrel, and a shaking table serves for concentration of the amalgam. Mr. Menzies, who evidently understands his work well, is aware of a loss of fine gold, which is frequently increased by a too limited supply of water. This serious want, which affected all the companies on top of the range from the commencement, will shortly, however, be removed, and the gold mining interests of the district generally will be greatly benefited by the completion of an extensive race, carrying a powerful stream of water, constructed by the Carrick Range Water Supply Company.

The Heart of Oak Company.—Managed by Mr. Thomas Scott.—The prospects of this company are of a high order; for its ground, which is west adjoining that of the Star of the East Company, encloses three proved auriferous reefs, viz., the Old Star of the East Reef, the Old Heart of Oak Reef, and the so-called North Reef, whilst a fourth, viz., the new reef of the Star of the East Company, just described, is worked up to within a short distance of its boundary. The Old Star of the East Reef has been worked with good results from the old adit of the Star Company up to and a good distance along the surface, and looks promising ahead; and, besides, what appears like a continuation of it, though called the *New Reef*, has a short distance higher up the range been taken out

for about 30 feet in length and 30 feet in depth, and proved payable, though only six inches thick. The Old Heart of Oak Reef, one of if not the richest in the district, strikes W. 25° S., and dips northward at an angle of 56 . It joins the Old Star of the East Reef, and has been worked, both from the upper adit of the Star Company and from the surface, a length of about 120 feet, and 160 feet in depth on the underlay. Its thickness varied from a few inches to over three feet ; average, about two and a half feet. There have been from 2000 to 3000 tons of stuff raised and crushed from these workings, which realised at the rate of 1¾ oz. of gold per ton. Prospects where left off working still very good.

The *North Reef*, which has been opened on top of the spur several chains west of the previously mentioned workings, strikes W. 15° S., and underlays southward at an angle of 70°; but frequent jumps render the underlay much flatter in the average. From its outcrop at the surface it shows an endlong dip in strike westward. It has been opened by a shaft 100 feet deep, and worked to a depth of 70 feet and 70 feet in length, proving from six to eighteen inches in thickness, and yielding from 1¾ to 4 oz of gold per ton. Pressure of water in the shaft prevented farther working. As the same difficulty attached also to the deeper working of the other reefs, the company have lately started on the same slope as, but considerably lower than, that of the Star of the East Company, a deep adit, which, according to Mr Scott's survey and calculation, would intersect the reef farthest off, viz., the Old Heart of Oak, in dip, at a distance of 800 feet in, and at about 300 feet vertical, or 500 feet depth on the underlay.

The Elizabeth Company.—Managed by Mr. John Towan. This company is, like the previous ones, engaged in driving an adit for the purpose of opening the Elizabeth Reef in depth, the backs from an upper adit towards the surface having been worked out. The lower adit, which runs nearly at right angles towards the reef, had, when I saw it, according to Mr. Towan's measurements, advanced to within about 100 feet of the point of intersection with the reef, from where a main level in the strike of the latter would render a height of backs of about 215 feet available for rising upon towards the main drive from the upper adit. The reef, which consists of quartziferous mullock, strikes S. 20° E., and dips eastward at an angle of about 40°. In the worked-out portion, which is about 270 feet long, and extends from the surface down to the level—a depth of about 180 feet beneath the highest point of the hill which the reef crosses—the thickness of the latter has ranged from eighteen inches to, in places, three and four feet—average, about two feet—and its walls were well defined. The yields have been from 8 dwts. up to 25 dwts., or close upon 13 dwts. of gold per ton in the average. About three and a half chains from the point where the main drive starts from the adit, which latter

has been driven at nearly right angles towards the reef, a shaft has been sunk on the underlay of the latter to a depth of 65 feet, and a level extends southward from the bottom a length of 90 feet, all along which distance and down the shaft the reef has proved highly payable—a point which augurs very well for the prospects of the deep adit. In fact, judging from the mode of occurrence of the best stuff in the old workings, as shown on a small plan prepared by Mr. Towan, there can hardly be a doubt that it forms a pretty wide shoot, which, whilst passing the just mentioned shaft and level, dips steep southward in strike, and would be struck by the adit pretty near the centre of its width. In its course northward the reef—being two feet thick—is suddenly cut off by a mullocky cross reef, striking W. 15° S., and dipping southward at an angle of 65°. The line of the unmistakable fault runs across the upper main drive about 40 feet southward from the upper adit, which has been continued about 200 feet farther westward in search of the faulted portion of the reef, but intersected only the faulting cross reef and a thin gold-bearing leader; whilst a cross-cut northward from near the end penetrated the former a second time, without any sign of the reef being apparent beyond. If these workings, in view of the distance driven, furnish already nearly certain proof that the reef has not faulted in that direction (westward), the mode of fault itself (angles and line of intersection of the two reef.) would also, according to an old mining rule, indicate that the throw has been the reverse way or eastward; and as the adit has, within about 70 feet eastward from the line of the reef, intersected a thin mullock reef, showing apparently the same strike and underlay as the latter, I think it highly probable that this represents the faulted portion. A drive on it southward in strike to its point of intersection with the cross reef would, whilst proving its auriferous character, soon dispel any doubts on the question. The cross reef, which is from one to one and a half feet thick, and looks much like the main reef in character, would also, in my opinion, deserve a trial crushing. Mr. Towan came across a second fault in the reef in its line of dip during sinking the underlay shaft from the main drive; but in this instance he soon recovered the faulted portion by intelligently applying and working according to the main mining rule, viz., that the part of the country with the enclosed lode, forming the hanging wall of the faulter, slid down in the line of dip of the latter.

The crushing machine of the Elizabeth Co. consists of two batteries, each of four heads of revolving stamps, of about 4 cwt. each, driven by a steam engine and having front and back escapes. The front escape of each battery passes in succession a large amalgamated copper-plate, an improved amalgamated copper-plate table, (similar in construction to that described of the machine at the Saddle Hill Reef) and 10 feet of blanket strakes, having an inclination of 1½ inches per foot. The back-escape of both batteries runs

over a common amalgamating table, and 14 feet of blanket strakes, laid at the same inclination as the others. For the treatment of the blanket sand, serves a small Berdan machine. This elaborate system of appliances is carefully superintended by Mr. Towan, but having to use the frequently limited supply of rather muddy water leaving the United Star and Oak Battery, he has no doubt of a great deal of fine gold being lost in the tailings.

The Young Australian Reef.—This lies close upon 1000 feet higher up the range than Carricktown, near the head of Adam's Gully, and the claim worked on it is owned by Messrs. Williams and Edwards. It strikes about S.E. and N.W., and dips N.E. into the hill at the very small angle of 18°. Walls pretty well defined. Its thickness ranges from $1\frac{1}{2}$ to 6 feet, in places, and it consists of quartziferous mullock, so fine in grain, that on washing prospects, pieces of quartz the size of a bean, are very rarely observed. An adit of 150 feet in length cut it about 85 feet from the surface, on its underlay, and it has at this level been followed by a drive a distance of 250 feet, and worked out about 140 feet in length, by 30 feet high; its flat dip, combined with the soft nature of the hanging wall, having given Mr. Williams some trouble, and taxed his ingenuity in securing the workings in an economic manner, by timbering and walling up with waste, combined. From the drive two shafts have been sunk 33 feet on the underlay of the reef to the water level, and proved it to be down to that depth of the same character as in the upper workings. About 160 feet S.E. from the end of the latter, the reef has also been struck, of a very promising character, by a shaft at a depth of 60 feet from the surface. The quantity of stuff hitherto crushed from all parts of the mine, amouunts to between 800 and 900 tons, which realized at the rate of $21\frac{1}{2}$ to nearly 25 dwts. of gold per ton. The gold which, judging from a good prospect washed in my presence from a tin dishful of the mullock is indeed very fine, seems to be pretty evenly distributed throughout the latter, Mr. Williams having observed neither shoots nor patches throughout the extent of the above workings. There have also been two other reefs discovered in the claim, viz., one of about two feet in thickness, running parallel to, and at a distance of 40 feet from, the one described. This has been opened for some distance, and the stuff obtained from it—none of which has yet been crushed—would, according to prospects washed, yield about 10 to 12 dwts. per ton. The second new reef is a cross reef, striking N. and S., and dipping E. at an angle of about 18°. It is from a half to two feet thick, and would, according to Mr. Williams' trial washings, pay from 1 to $1\frac{1}{2}$ oz. of gold per ton. From all I have seen of this mine, and considering that the ground lower down the gully offers facility for putting in an adit at a considerably lower level than the present workings, and more in the direction of the strike of the main reef, I think it represents one of the most promising

ones in the district. In anticipation of obtaining the necessary supply of water from the large race of the Carrick Range Water Supply Company, the proprietors had a fine crushing plant (purchased from the Conroy's Gully Reef Company) in course of erection by Mr. Reid, the well-known mining engineer. The plant consists of two batteries, each of five heads of revolving stamps, to be driven by an iron water-wheel, common amalgamating tables, and 14 feet of blanket-strakes. On my representation, they seemed inclined to add deep quicksilver troughs, or to substitute them for the amalgamating tables.

The Leader.—This is a mullock reef worked by E. Jones and Company, a short distance from the Young Australian, higher up the gully. It has been opened by adit, and proved for about 150 feet in length, showing a rather irregular course at a mean strike of S. 15° W., and an eastward dip at 35-40°, whilst its thickness varied from a few inches to several feet. The yields from three crushings have been at the rate of 11 dwts., 28 dwts., and from the last 22 dwts. of gold per ton. The gold is very fine, and hardly ever visible in the mullock. Prospects of the reef still good.

The Stanley Reef.—This crosses the range a short distance west of the Leader, and is being opened by Buchan and Company. It strikes W. 15-20° S., and dips northward at an angle of 60-65°. According to Mr. Buchan, it has been traced in an unbroken line for over 1,200 feet in length, *i.e.*, much farther than any other reef on the Carrick Range. In most of the places, where it has been opened on the surface, it is small and contains a little gold all through, but where the adit is in, its thickness is 2 to 2½ feet, and it gives prospects at the rate of 14 dwts. of gold per ton. In the shaft which is being put down on the underlay of the reef, the latter is pinched to a few inches, but is now making again, and the stone of the "new make" is good-looking and differs from that on the surface, which was like that of the generality of the reefs on the Range, mullocky.

The Royal Standard Reef.—Mr. Buchan supplied me about this reef with the following information :—It is situated about 600 yards north of the Stanley Reef, and is the one first discovered on the Carrick Range, and also the richest, having yielded at one time 7 ozs. of gold per ton. Its strike is nearly due N. and S., and its dip east at an angle of about 20°. It was abandoned on account of its small size, but another company has just taken it up again, and it will now be tested in depth.

The Kohinoor Reef.—Mr. Buchan states about this as follows : It lies about ¼ mile N.E. of the Royal Standard Reef. Its strike is about N.W. and S.E., and it dips very flat towards N.E. It is large, well-defined, but very poor, only giving about 5 dwts. of gold per ton. The workings extend only to a depth of about 100 feet. There

was a patch of good stone on the surface. The claim was ruined through bad management.

The Marquis of Lorne Reef.—According to Mr. Buchan, this lies a few hundred yards farther north and nearly adjoining the John Bull Reef, mentioned further on. It strikes about E. 20° N., and dips southward at an angle of about 30°. The reef is small and consists of very hard, white quartz. A crushing was taken out which yielded over one ounce of gold per ton. It was not tried at a greater depth than 60 feet when it was abandoned.

The All Nations Reef.—According to Mr. Buchan, this is an isolated reef lying ¾ mile south of the Stanley Reef, and the same distance west of the Young Australian. It is also a flat reef of good size, and has averaged over one ounce of gold per ton. The expense in working it is very great on account of the distance, everything has to be carted. Only lately a road has been made to it, previously, everything had to be packed. The strike of the reef is about N.W., S.E., and it is almost horizontal, at least much flatter than the Young Australian. The stuff is crushed at Logan's machine, which lies about 3 miles from the claim.

The Colleen Bawn Reef.—Mr. Buchan states that this is another abandoned reef, which was once worked by a Joint Stock Company, whose shares were at one time selling at a high figure. The strike of the reef is about due N. and S., and its dip E. at a very slight angle. A good number of crushings were taken out and averaged about one ounce of gold per ton. The reef is small and in no place more than 18 inches; it would not average more than 9 inches in thickness. The top and bottom walls are exceedingly hard. Were it not so, the reef could be profitably worked, as it is adjoining the Elizabeth and Heart of Oak, and within a few yards of a battery.

*The Vale of Avoca Reef.**—This lies according to Mr. Buchan, at the north end of the same spur, as the Colleen Bawn is on. It is a large mullock reef running N. and S. with a very slight dip towards the east. The last crushing gave 14 dwts. of gold per ton, and were it not in a very awkward place to get to, it could be worked profitably. The quartz had to be packed a part of the way, sledged another part and carted the remainder of the way to the crushing machine. A little capital would make a road which might make the reef pay handsomely. Several adits are put in on this reef at different levels. It was taken up a short time ago, and another adit is being driven which will give about 200 feet overhead. At the lowest level the prospects are better than on the surface.

The Robert Burns Reef.—This lies about a mile west of Carricktown, low down the north slope of a steep spur, near the head of Pipeclay Gully. It is about 2 feet thick, strikes E. 20° S., and

* The Royal Standard, Kohinoor, Marquis of Lorne, All Nations, Colleen Bawn, and Vale of Avoca Reefs I did not visit, and all the information given has been supplied to me by Mr. Buchan, of Carricktown.

dips northward at 55°. Its walls appear pretty well defined. Crushings have yielded 25 dwts. of gold per ton. The gold ran out in depth, but may likely have dipped eastward in strike.

The Nil Desperandum Reef.—It lies nearly in a line with, and only a few chains S.E. from the former, but strikes S.E. and dips vertically. Some satisfactory returns have been obtained from it, but it became also unpayable in depth.

The John Bull Reef.—This runs about 9 chains higher up the slope, near the top of the spur, south abreast of, and parallel to to the Nil Desperandum, and dips N.E., *i.e.*, towards it at an angle of 45°. According to Mr. Buchan, it is one of the most extensively worked reefs on the range, and has proved to a depth of over 200 feet. Down to that depth it was very small and averaged about 15 dwts. of gold per ton. These last three reefs which have been deserted for some time, ought, according to their strikes and dips and mutual position, to unite not far up the range; and to test the junction of the John Bull and Robert Burns reefs in depth, Griffiths and party are at present engaged in continuing the adit of the Old Golden Gate Company (who originally worked the reefs), in the calculated direction. This is no doubt a very promising undertaking, for the junction of the reefs may likely prove richer than each reef proved by itself. That one reef should have faulted the other, I see no reason to apprehend.

Not far from the Robert Burns Reef, in the gully, stands a small public crushing machine, owned by Logan and Company. This consists of a battery of 5 heads of revolving stamps, about 6 cwt. each, driven by a steam-engine, with arrangement for introducing hot water into the coffers. The saving of the gold is effected on a common amalgamating table, and 14 feet of blanket strakes, with 2-inch fall per foot. For the treatment of the blanket-sand, serve a revolving barrel and a shaking table. I have also to notice another public crushing machine, viz., that of the Old Royal Standard Company, standing near Quartzville, at the foot of the Carrick Range. This consists of two batteries, each of 4 heads of revolving stamps, fed by hand and driven by a steam-engine. As gold saving appliances are used, common amalgamating tables and 10 feet of blanket strakes, laid at an inclination of about 2 inches per foot. From what I could see, there seemed to be danger of grease from the stampers dropping into the coffers. This should most carefully be guarded against; for grease not only prevents the quicksilver from acting upon the gold, but has also a strong tendency of flouring it.

APPENDIX 8.

Reefs and Companies of Arrow.

In this district there have not been any regular reef workings

carried on for a long time past. I collected, however, some information on the principal quartz mine once worked, and examined also, conducted by Mr. Innes, the mayor, Mr. McDougall and other gentlemen interested in quartz-mining, two promising reefs formerly prospected.

The Old Criterion Company's Reef.—This reef, which had once a high reputation in the district, runs in the flat close along the Arrow River, near Arrowtown. Judging from the old surface workings extending for about 5 chains in length, it strikes W. 35° N. and dips at 80 to 90° eastward towards the river, crossing the country—a soft mica schist—both in strike and dip. There have been rich drift-workings close alongside of it. The following particulars about the reefs and the operations of the old Company, were kindly furnished to me by Mr. H. J. Cope:—The reef was discovered in 1864 by a Victorian quartz miner, and is the one first opened in the Province. It consists of a clayey mica-schist mullock, enclosing veins and bunches of quartz. Besides being worked for a good length from the surface, a shaft was sunk on it to a depth of 120 feet, from which it was worked out from 90 feet down, up to the surface, and 70 feet in length. There was not much water coming in at the bottom of this deep shaft. Another shaft was sunk on the reef at the south-east end of the open workings, about 40 feet deep, and it was followed from this for 80 feet in length. In the main-workings it was at first taken out from one to four feet in width, but another manager subsequently broke into what has been considered the foot wall, and worked several feet of it, which paid nearly as well as what had been previously taken. A leader was found joining the reef which also contained good gold. The yields from the crushings ranged at first from $\frac{1}{2}$ to $1\frac{1}{2}$ oz. of gold per ton, average about 1 oz., but gradually fell off to $\frac{1}{2}$ oz, which would not pay at the time, and the mine was therefore given up. The gold was no where completely lost in the workings; but the best seemed to occur in a shoot, dipping westward in strike. The company had a small battery of five heads of stamps, with a common amalgamating table and blanket-strakes in front, the whole poorly constructed. Much difficnlty was experienced in clearing the boxes on account of the mullock being of a very clayey nature, and all accounts agree that a great deal of the fine gold was lost. The management was altogether very bad, for it took about twenty men to keep the small battery going. The shares of the company were at one time at a very high premium, and the coming to grief of the mine subsequently has been the principal cause of destroying confidence in quartz mining in the district, and that prevented the latter from being properly prospected since. Considering all the different points relating to the auriferous character of the reef, the workings, management, &c,, in connection, I cannot help coming to the conclusion that the reef certainly deserves another trial, and that this,

if effected in an economic and systematic manner, and with the use of good crushing machinery, might likely prove a very profitable speculation.

The Cornish Reef.—This lies on the Crown terrace, about a mile eastward of Arrowtown, and has lately been taken up by M'Whirter and party. It strikes S. 40° E., and dips very nearly vertical, *i.e.*, south-westward, at about 85°, showing well-defined walls, with thin clay casings, and crossing the country—a fissile, nearly flat-bedded mica schist—both in strike and dip. Its thickness is nearly five feet, of which one and a half feet along one wall consists of good-looking quartz, full of pyrites, the remainder of quartziferous mica schist mullock. The prospectors found good gold in the quartz, and opened the reef by a small shaft, since collapsed, and a small drive; but none of the stuff has been crushed. Running at nearly right angles across a steep gully, the reef could be easily opened in strike by adits, either side, attaining, at but a short distance in, a depth of at least 150 feet beneath the surface of the bounding hills: and this trial it decidedly deserves. There is a good fall for the waste down the gully, and from a race higher up on the Crown Range a sufficient supply of water might, perhaps, be secured for a small crushing machine. About 15 feet above the reef a good-looking, well-defined leader, about one foot thick, is exposed in the gully, which strikes E. 15° to 20° S., and dips at an angle of 80° southward—a course according to which it ought to join the reef at a short distance towards the west. To prospect this leader would also be advisable.

The Columbia Reef.—It lies about a quarter of a mile from the former reef higher up the gully, near the top of the terrace, being exposed in a narrow rift in the southern hill slope. It strikes S. 25° E., and dips close upon vertical. Thickness from six to eight feet, mostly composed of solid, rather hungry-looking quartz. It has been prospected by a shallow trench, about 40 feet in length and gold is said to have been seen in the quartz ; none of the stone has, however, been crushed. This reef is not as promising looking as the foregoing ; yet, as it could be easily opened by a small adit in strike, it might not be unadvisable to give it this trial.

ALLUVIAL COMPANIES.

Arrow Flat Deep Lead Company.—This company, of which Mr. Elliot is the manager, obtained very rich prospects from what appears to be an old channel of the Arrow River, trending across the present River Flat towards the old Lake basin beyond Arrowtown. In trying to work the ground a large amount of water was, however, encountered, issuing from a loose shingle bed, about 10 feet beneath the surface, and being fed, as examination proved, by a strong creek, which joins the valley a short distance higher up. The erection of strong pumping machinery was, therefore, resorted to, but even this, though consisting of two 12in. drawing-lifts,

driven by turbine, and working incessantly day and night, has hitherto failed to make any sensible impression upon the water in the shaft. A dry season would no doubt greatly assist the company, but as this might be hope too long deferred, I see no other way of quickly beating the water than the erection of additional or more powerful pumps. A Victorian plan in such cases of emergency might also deserve consideration, viz., to sink a good shaft in the rock near outside the water-bearing drift-bed, drive from this a rock-level underneath and in the course of the lead, and to open and work the latter by means of rises from it. The putting down of a number of bore-holes, for the purpose of ascertaining the depth and trend of the lead, would of course be a necessary preliminary.

Sons of Fortune Gold Mining Company.—This Company, under the management of Mr. Miller, is at present engaged in a highly promising enterprise, viz., in driving an adit into an enormous land-slip, which backs up the Arrow River, considerably over 100 feet in height, at a place lying about four miles up the river from Arrowtown. Judging from the workings higher up, there is no doubt rich washdirt existing at the bottom of the valley above the landslip; but all attempts to reach it by shafts, one of which is 42 feet deep, have hitherto failed, on account of too strong a pressure of water. The adit is intended for draining the little basin, and thus affording access to the washdirt, and it might also afterwards be made use of as a tail-race. It was, at the time I saw it, about 70 feet in, and would, according to Mr. Miller's calculation, have to become about 300 feet longer. The working requires very great care, on account of the uncertain nature of the ground—large boulders, dangerous to remove impeding the way frequently.

APPENDIX 9.

Reefs and Companies of Skipper's Creek.

Nugget and Cornish Company's Mine.—This mine lies on the N.W. side of the Shotover River, and is managed by J. F. Roskruge, who readily furnished me with all the required information. The Nugget and Reef strikes W. 43° N., and dips south-westerly at angles varying from 70° to 80°. It has well-defined walls, with clay casings, and crosses the country—a very fissile argillaceous mica schist—both in strike and dip. The present workings of the company, of which Mr. Roskruge prepared a detailed plan, are carried on from an adit, in an enormous slip, and are, on that account, of an intricate nature, and require great care in rendering them secure, as the reef varies there in thickness from 12 to over 20 feet in places. The adit is in a distance of 197 feet, of which the last 144 feet are on the line of the reef. The latter consists of quartziferous

mica-schist mullock, with veins and bunches of quartz, sometimes several feet thick. Both the mullock and the quartz are very abundantly impregnated with iron and arsenical pyrites, and contain gold, but the quartz is generally the richest. The average yield has hitherto been eleven to twelve dwts. of gold per ton. The reef is traceable for a very long distance. High up the steep mountain side, N.W., a strong leader was worked in its line by another party, and paid $4\frac{1}{2}$ oz of gold per ton. Down the steep slope towards the Shotover River, below the slipped ground, it is plainly exposed, from 8 to 10 feet thick, and from there—some 180 feet perpendicular below the present workings—Mr Roskruge very wisely intends putting in an adit, which will give about 250 to 270 feet of backs to rise upon. Beyond the river, up the opposite high and steep range, it has also been opened at several places and proved auriferous. There is another reef about 200 feet distant from the above described, higher up the mountain side, which strikes W. 35° N., and dips at an angle of about 50° towards it—the line of junction of both reefs in dip lying, according to Mr Roskruge's calculation, perhaps close to the end of the working adit. This reef is from 10 to 12 feet thick, and has been worked down from the surface, also in the slipped ground, a depth of 100 feet, but there is still a good height of backs available above the adit. The yields from it have in the average been about 16 dwt. of gold per ton. As regards the whole quantity of stuff crushed from the mine, it amounts to 6958 tons, which have realised $3624\frac{1}{2}$ oz. of gold. The crushing machinery of the company, which stands close to the Shotover River, consists of three batteries, each of four heads of revolv-stamps, of about 6 cwt. each, fed by hand, and driven by a turbine. As gold-saving appliances, are used amalgamated plate-boxes with three drop-ripples, similar in construction to those of the Elizabeth Company's machine, Carrick Range, but improved by the addition of splash-boards for ripples. From these boxes, of which there are three—one for each battery—the stuff runs over only six blanket-strakes of 12 feet in length, and with a fall of $1\frac{1}{2}$ inch per foot. The blanket-sand is treated in the revolving barrel, and the amalgam concentrated on a strake, covered with amalgamated copperplates. A similar, though longer strake, with a ripple at the end, serves for washing the stuff from the stamper-boxes. On account of the great amount of pyrites in the stone, much quicksilver is lost through becoming floured, and Mr Roskruge is also convinced of a considerable loss of fine gold. He intends soon to entirely rebuild the machinery, which is old and liable to frequent breaks, so much so, that only about 50 tons can be crushed per week, and he took notice of my recommendation to adopt the Clunes system of appliances. In reviewing my observations on this mine, I feel convinced that, if worked on the extensive scale which the size of the reefs and facilities of the ground permit, and with adequate good crush-

ing machinery, it would become one of the best paying ones in the Province.

Southberg's Reef, Otago Company.—Managed by Mr Southberg. This reef, which is traceable for several miles in length, crosses the country both in strike and dip, striking E. and W. and dripping N. at angles varying from 35° to 60°. It has been opened from Skipper's Creek both ways by adits, but the most extensive workings have been executed on the east side. The western adit is about 200 feet in length, and the reef, where broken into by a small cross-cut near the end, is 22 feet wide, representing in fact an enormous fissure, with well-defined walls and clay casings, filled with the country rock—a fissile, quartziferous mica schist, not very much altered or displaced, but richly impregnated with pyrites. Of veins and bunches of quartz, independent of the interlaminations of the latter, in which the country in this district is very rich, there are but a few observable, and the mass, as such, is altogether too poor to pay for working. On the east side of the creek the reef carried rich gold (1 to 9 oz. per ton) for a considerable distance along the surface, ranging in thickness from eight to sixteen feet; but on working downwards it was found to run poor at depths increasing towards the east, and the present low adit, though a considerable distance in, has not as yet struck it of a payable character. At some of the places opened it is from 12 to 14 feet thick. There are several drives branching off this adit, which have been wrought for the purpose of prospecting a strong spur, or dropper, which dips flat away from the reef, and has produced good gold in the upper workings higher up the range. As far as this spur has been opened by the drives it has not, however, proved payable as yet, though Mr. Southberg does not despair of finding it so on further exploration. It is in places from two to three feet thick, but thins gradually to a mere string as it approaches the reef. Considering the run of the good portion of the reef worked on this side, there can be no doubt that it represents a shoot dipping at a rather flat angle eastward in strike out of the company's lease; and on this account, I fear, Mr. Southberg has no chance of finding payable ground—a new make—except in sinking from the present eastern adit. On the west side the prospects are, in my opinion, far more favourable; for the adit, if continued along the reef, has there a good chance of striking a new auriferous shoot, the existence of which is clearly indicated by good specimens and prospects having been obtained from the outcrop of the reef higher up the range. The present productive workings of the company are carried on in another claim high up the eastern range, in a large landslip enclosing the reef, similar as in the case of the Nugget and Cornish.

The crushing stuff from these workings contains abundance of vein quartz, and is very ferruginous, resulting from decomposed

pyrites, though the latter occurs also intact in pretty considerable quantity. The exact yield of the crushings was not given, but from what I could gather, it does not amount to much above 5 dwts. of gold per ton.

The crushing plant of the Otago Company consists of sixteen heads of revolving stamps, in four batteries, fed by hand, and driven by a turbine at a speed of about 60 blows per minute; weight of stamp, 6 cwt.; lift, only five to six inches; gauge of gratings, which are punched, 122 holes per square inch. The arrangements for gold-saving for each battery are as follows:—The stuff passes in succession a shallow mercury ripple, two and a half feet of copper-plate, two blanket-strakes, four feet long; a rather narrow mercury ripple with a five-inch drop; and two blanket-strakes of six feet in length. Both the lower and upper strakes are two feet wide, and lie, in front of two batteries, at an inelination of one and a half inch per foot; in front of the other two, at one and a quarter inch per foot. The blanket-sand, which is very rich in pyrites, after being merely washed by tin-dish and in a strake, is left to decompose by exposure to the atmosphere, and is then passed again through one of the batteries, with gratings of 225 holes per square inch. Mr. Southberg knew that on aceount of the large quantity of pyrites much quicksilver was being floured and a great deal of fine gold lost, and he seemed inclined to adopt the Clunes system of appliances I recommended.

Phœnix (late Scandinavain) Company.—The ground of this Company, also on Southberg's Reef, adjoins that of the Otago Company on the east, and, according to a plan, and seetions prepared by Mr. F. Evans, the consulting engineer of the Company, has been extensively worked by and from several adits driven from the steep slope of the range. As these workings were inaccessible, I could not examine them; but from what I learned from Mr. Evans, the reef, which averages in them 8ft. in thickness, contains what appears like two large payable shoots (the yields varied from 6 to 25 dwts of gold per ton), dipping eastward in strike, and there is besides the chance of the rich shoot coming from the Otago Company's ground, above-mentioned. The quartz, and this is the case in the latter company's ground also, changes in character from crystalline and brown ferruginous in the higher to dense and bluish grey in the lower parts of the workings—in fact, the latter quality represents a so-called "new," or "second-make." On examination of specimens, I found it densely impregnated throughout (the cause of its dark color) with extremely fine particles of pyrites (iron pyrites with much arsenical and copper pyrites), and showing gold in very fine specks. It looks in texture more brecciated than seamy. The reef will in future be worked by and from a new deep adit, which, at the advice of Mr. Evans, has been driven from Skipper's Creek, and struck the reef at a distance of 347 feet,

from which level there would be about 160 feet height of backs available to rise upon. As regards the crushing machine of this company, erected about 8 years ago, and at present much out of repair through long disuse, it is the largest in the Province, and its system of gold-saving appliances resembles most closely that of the Port Philip Company, Clunes. It consists of 30 heads of revolving stamps in 6 batteries, each of 5 heads, supplied with self-feeding hoppers and driven by a powerful turbine in the centre. The coffers are of the Clunes pattern; weight of stamps over 6 cwt.; lift, 6-8 inches; gratings punched with 122 holes per sq. inch: at one time gratings of wire gauze were used, with only 81 holes per sq. inch. The stuff passes from each battery through three connected quicksilver troughs, with 8 inches drop, and supplied with splash-boards, and afterwards over blanket strakes of 14, 16, and 18 feet in length, for different batteries; some with 1, others with 1½ inch fall per foot. The quicksilver troughs are rather narrow, and concave at the bottom, which is not as good as if they were flat, as the quicksilver is more liable to be splashed over in front. The stuff from the stamper-boxes is washed in a large tie. For the treatment of the blanket sand, which is very rich in pyrites, serve a large revolving barrel with a broad shaking table and rippled ties attached; and after passing these appliances, it is put aside to be ultimately ground with quicksilver in a large arrastra, for the purpose of extracting the gold from the pyrites. The yield of the sand by this latter process has varied from 3 to 12 oz. of gold per ton; loss of quicksilver not ascertained. There is also a reverberatory furnace, built after the old Cornish model, within the mill house; but this has not been in action for the last six years, on account of the fumes being unbearable and dangerous to the men working in the building. According to what Mr. Evans told me, he understands the process of the extraction of the gold from the pyrites well, and intends to build and work another furnace after the Victorian model, outside the mill. Besides this, he purposes erecting in front of the batteries several Borlase's buddles to ensure a more satisfactory saving of the pyrites. With these contemplated improvements executed—considering the capabilities of the mine, as stated by Mr. Evans—it ought to rank soon amongst the dividend-paying ones of the Province, more especially if the occasional short supply of water for the crushing works is obviated by the construction of the proposed new race. There have been a number of other claims and reefs worked in the district, of which Mr. Evans kindly gave me the following particulars:

British American Claim.—It lies on Southberg's Reef, 600 feet east, up the range. The reef, being there 3 to 4 feet thick, was opened by a shaft and the stuff obtained paid 11½ dwts. of gold per ton. The party then drove to an adit to strike the reef about the site of the shaft; but having had no survey for guidance,

went nearly 300 feet out of the line, and never reached the reef. There has been nothing done since in the claim. Between 300 to 400 tons of stone were crushed by the machine of the Nugget and Cornish Co., which once belonged to the party.

Prince of Wales' Reef—Is a continuation of Southberg's Reef, westward, high up the range. It was from 15 to 20 feet thick where opened, and paid from 7 dwts. up to 1 oz. of gold per ton; but the stone crushed was mostly picked.

Pactolus Reef—It lies north of the Prince of Wales' Reef, is about 6 feet thick, and has a north and south strike. The prospectors opened it for 20 feet in length, and had a trial crushing which yielded at the rate of 6 dwts. of gold per ton. As this did not pay for working, it was abandoned, and has not been further tried.

Sawyer's Gully Reef.—It was 3 to 4 feet thick on the surface, but pinched in depth. Three tons were crushed, which yielded 4 ounces 12 dwts. of gold. There has been nothing done on it since.

Butcher's Gully Reef.—This was 20 feet wide where opened, and a trial crushing paid 7 dwts. of gold per ton. After this it was not further tried. The gold it carries is very fine.

Ophir Reef.—This lies about half a mile from the Nugget and Cornish Reef, up the Shotover River. It is plainly exposed in a landslip, and carries fair gold. The prospectors spent £600 to £700 in trying to find it in undisturbed ground, but without success. The mode and manner of conducting the search, has not, however, been the most judicious, according to most opinions.

Hercules Reef.—This is a continuation of the Nugget and Cornish Reef. Where opened, it was 5 to 6 feet thick, and a trial crushing paid 5 to 6 dwts. of gold per ton. Although better stone was known to exist, it was given up, and has not received any further trial.

Southland Reef.—This lies about one mile south of the Hercules Reef, nearly 600 feet above the Shotover River. It is a mullock Reef with bunches of quartz, which are more or less rich in gold. A yield of 45 ozs. was obtained from 14 tons crushed. One of the prospectors was killed during working, when afterwards a shaft, sunk on it to a depth of 50 feet, struck much water, it was deserted, and nothing has been done on it since.

APPENDIX 10.

Reefs of the Rough Ridge.

In visiting this district we were accompanied by Mr. James Hazlett, M.P.C., who kindly afforded me some information about the drift workings of Tinker's and Drybread, passed on the road. At the Rough Ridge we found only one enterprising man, Mr. Withers, employing labour in reopening a reef, once worked by the old Ida Valley Company, though over twenty other auriferous reefs are said to have at one time been worked in the district. The reef Mr. Withers is engaged reopening, and about the history of which, and a number of others—the principal ones formerly worked—he kindly afforded me the subsequently given particulars, is the *Homeward Bound Reef.* The old main openings, from which exploitation has been carried on, consist of an adit 770 feet in length, driven from a gully in the strike of the reef; and of a shaft sunk from the hill slope a depth of 110 feet, passing the adit at about 50 feet from the surface. The reef is not a solid and defined one, but consists of a series of quartz leaders, of varying length and thickness, running close together in a defined line of strike, viz., E. 30° S., and dipping steeply towards each other. Some join also in strike, and, whilst one ceases, another generally commences sideways, or a few feet further on. This band of leaders, which is traceable for a considerable distance S.E. up the range, traverses a fine blue phyllite, which dips slightly westward, and looks much disturbed by joints and faults, which also affect the leaders. A fault of several feet in one of the strongest of the latter is, for instance, observable in the vertical shaft, where this passes the adit. It is not at all unlikely that the country becomes more settled, and some of the main leaders join and form a defined reef in depth. This seems to be indicated by a body of fine looking quartz—4 feet thick and carrying payable gold—having been struck and left at the bottom of the shaft. Mr. Withers, who is at present engaged in taking out some payable stone from what appears to be the main leader, left by the old company underfoot of the adit, intends soon to try his chance—and it is, I think, a very good one—in depth by sinking a main shaft near the mouth of the adit. For, irrespective of the probability of finding there a strong, defined reef, from what he observed about the run of the gold, it seems to dip in shoots north-westward, *i.e.*, from the hill towards the gully, where the adit commences. The quartz of the leader worked, which is but slightly mixed with mullock, shows a fine seamy structure and is abundantly impregnated with iron and arsenical pyrites, whilst the richer gold-bearing stone is characterised by additional impregnated particles of zincblende and bournonite. The old Ida Valley Company had a fine crushing machine—the one bought by the Alta Company, Bendigo, noticed at another place—but they worked it very badly, and lost, besides

gold, a large quantity of quicksilver, some say nearly a ton weight in a short time. Mr. Withers' crushing machine consists of a battery of five heads of revolving stamps of $5\frac{3}{4}$ cwts. each, fed by hand, and driven by a small steam engine. He uses gratings with 122 and 144 holes per square inch, but generally the former. The crushed material, on leaving the battery, passes first through three shallow quicksilver ripples, then over a common copperplate table, and ultimately over three blanket strakes, about 16 feet long, and laid at an inclination of $1\frac{1}{2}$ inches per foot. For the treatment of the blanket sand are used a revolving barrel and a shaking table. As Mr. Withers knows from small experiments, that the pyrites, which forms a large percentage of the sand, is richly auriferous, he preserves the latter for future re-treatment. The Clunes system of appliances, which I described to him, seemed much to please him, and he may likely give it a trial.

Lloyd's Reef.—This runs at a distance of about 100 feet southwestward from, and parellel to, the Homewardbound Reef. Besides having been worked also by the Old Ida Valley Company—by small shafts here and there along the surface, it was opened by a crosscut from near the southern end of the adit on the above reef, and proved, where struck, to be about six feet thick. On driving on it, a fault was found to cut it off close to this point north-westward in strike, and the faulted portion was not recovered; south-eastward it continued, however, well-defined, though gradually thinning to about one foot, and was followed a distance of about 300 feet, and stoped out from the level to very near the surface—the quartz paying very satisfactorily. Mr. Withers intends prospecting for this reef—the above-noted faulted portion—by a crosscut from his contemplated new main shaft, and is not at all unlikely to discover it, judging from indications of the reef on the surface abreast of the mouth of the adit.

Great Eastern Reef.—This lies about $\frac{1}{4}$ mile north abreast of the Homewardbound Reef, and strikes S E. with a dip at an angle of 85° traversing very flat-bedded phyllite, and showing well-defined walls. It has been worked for several hundred feet in length, and 40 to 60 feet in depth, partly by open cutting, partly by and from an adit about 200 feet long. At the mouth of the adit a shaft was sunk on it a depth of 70 feet, when a strong pressure of water prevented further sinking without pumping machinery. At the bottom of this shaft the reef is said to be left 18 inches thick, and carrying better gold than found in the main workings. In these, its thickness ranged from a few inches to three feet—average, about $1\frac{1}{2}$ feet —and it consisted of quartz and mullock, the former much predominating. The gold occurred in shoots, dipping north-westward in strike, similar as in the Homewardbound reef. There have been several 100 tons of stone crushed with an average yield of about 1 oz. of gold per ton—the yields having ranged from 7 dwts. to 2 oz.,

and, from some narrow parts of the reefs, even to 3 ozs. of gold per ton. About three chains N.W. from the mouth of the adit, on a low rise, bounding the gully which runs up to the above workings, some open workings have been carried on, and small shafts sunk on what appears to be the continuation of this reef, and from these also some good gold is said to be obtained. The cause of the desertion of the reef by the Great Eastern party, who worked it first, and by the Energetic Company, who worked it subsequently, is said to have been partly bad management, partly want of enterprise in erecting the necessary pumping machinery for opening it in depth—a trial which it, in my opinion, certainly deserves.

West of England Reef.—This was formerly worked by the Sons of Temperance Company by an adit, open cuttings and shafts, about eight chains northward from the mouth of the adit on the Homewardbound Reef. It strikes E. 15° S. and dips northward at an angle of 56°. Its thickness ranged in the old workings from 6 inches to 18 inches, and it pinched and expanded at very short distances. The gold occurred in a shoot that dipped westward in a strike. A considerable quantity of stone was crushed, which yielded from 6 dwts. to $1\frac{1}{2}$ ounces of gold per ton. The reef has been traced by shafts several chains westward under the alluvial of a flat adjoining the workings; and as the gold struck was found to dip in that direction, it might not turn out a bad speculation to prospect it there, though on account of the water, no doubt to be met with, a horse-whim would likely be required in sinking below a shallow depth.

Surprise Reef.—This is a small reef only about one foot thick, and has not been much opened. 60 to 80 tons of stone crushed, yielded from 14 dwts. to $1\frac{1}{4}$ oz of gold per ton—a return which did not pay, as the expenses were too high at the time.

Queen of the Isles Reef.—It lies between the Great Eastern and the Homewardbound reef, near the line of the former, and was worked several years ago by the Ida Valley Company to a depth of about 40 feet. Its thickness ranged from 1 to $2\frac{1}{2}$ feet, and about 100 tons crushed from it paid from 10 to 17 dwts. of gold per ton. There has been nothing done on it since the company broke up.

New Reef.—This has lately been discovered by Mr. Withers, who is sinking a shaft on it. Its position is about $\frac{3}{4}$ mile northward from the Homeward Bound Reef. Whilst dipping nearly vertical it runs N.E., a course crossing the lines of all the other reefs. It consists of coarsely crystalline quartz, is about 7 inches thick, and has one good wall. A crushing of 28 tons gave the handsome return of $1\frac{1}{2}$ ozs of gold per ton. This reef crops out within a zone of country perhaps over a mile in width, which is full of a number of small reefs or spurs, 40ft. and less apart, running more or less parallel, of which many have been opened and proved auriferous.

Before leaving this district, I may mention what Mr. H. J.

Cope informed me of, namely, that at Sutton, Strath Taieri, a large reef has some time ago been worked by McIvor and Co., called the Recassoli Reef. This was about 7½ft. thick, and consisted of 6ft. of white quartz, with 18 inches of mullock running alongside. The first crushing paid 2 oz 9 dwts, the second 1 oz 13 dwts, and a third of twenty tons, 13 dwts of gold per ton, which latter did not cover expenses. The crushing machine used consisted of an atmospheric two stamp battery, driven by steam. The mullock vein, which was the gold-bearing portion, ran out in depth; of the white quartz, none was tried. From the fact that the gold, after retorting, turned out black, it is, no doubt with truth, surmised that some bad metal was in the stone, which caused a loss of gold during crushing.

APPENDIX 11.

REEFS OF MACRAE'S FLAT.

To this locality I was kindly conducted by Mr. Warden Robinson, of Naseby. At the head of Macrae's Flat there have been at one time several so-called reefs prospected and proved auriferous (Golden Bar Reef, Moonlight Reef, etc.), but according to description, they seemed to have only formed bunches, or "blows," between the beds of the country, running out in strike and dip. The only reef on which some extensive workings have been carried on is the Duke of Edinburgh Reef, and about the history of this and the old company who once worked it, I received ready information from Mr. A. Simpson, a former employé of the company. The reef, where exposed, in a small cutting from a gully near the old main workings, is 3ft. thick, strikes W. 20° N., and dips northward at an angle of 35° to 40°, lying between the beds of a rather soft blue phyllite that forms the country rock. The foot-wall, or underlying rock-bed, is well-defined and smooth, but the hanging one is broken and traversed by small quartz leaders, dipping towards the reef, which latter is composed of about 15 or 18 inches of quartz on the foot wall, and nearly 2ft. of mullock, traversed by quartz strings, on the hanging wall. The quartz is good looking and abundantly impregnated with pyrites. As regards the old workings, which consist of open cuttings and shafts, now more or less collapsed, they extend, with a few interruptions, for 12 to 15 chains in length; but the greatest depth reached at any point was, according to Mr. Simpson, only 40ft. The quartz, which was principally selected for crushing, ran from 10 to 18 inches in thickness, and paid from 7 dwts. up to 2 oz. of gold per ton. It was nowhere lost in depth. The reef, as such, is traceable for more than a mile in strike, and crosses two small gullies, which, from the crossing line downward, have proved very rich in gold, a clear proof that the denuded portion of the reef must have been richly auriferous also,

and indicating the chance of the latter being there payable in depth. The company's crushing mill was a very good one, but, judging from the coarseness and pyritous nature of the tailings, and that, according to Mr. Simpson, a large quantity of quicksilver was lost, a great deal of the gold, which was very fine, must have been lost also. On account of the scarcity of water in the locality, the company had a fine reservoir constructed in the gully below the reef, from which an adit led the water to a shaft, 50ft. deep, sunk close to the machine, and furnished with pumps for supplying the batteries. Considering the nature, extent, and auriferous character of this reef, and the, no doubt, considerable loss of gold during former crushing, there is, I think, some chance that, if economically worked, and with improved gold saving appliances, it might leave a profit, notwithstanding a great expense connected with the procuring of fuel (Brown coal from Shag Pont) for a steam engine.

APPENDIX 12.

REEFS OF SHAG VALLEY.

In visiting the locality Mr. Rich, of Bushy Park, and Mr. Harvey, of Dunedin, kindly acted as my guides and informants. The first reef I saw has been worked on both sides of a steep gully; on the one side, the most extensively, by Duncan, Glover, Reed and Company, on the other side by the Shag Valley Lease and Freehold Company. It consists of irregular larger and smaller bunches of quartz, ranging from less than an inch to several feet in thickness, lying between the beds of the country, a hard, bluish grey phyllite, which strikes N. 30° W., and shows an undulating dip north-eastward, at a mean angle of about 14°. Work was suspended on account of the uncertain thickness and auriferous character of the reef. A few chains higher up the gully a similar reef, or rather a succession of interlaminated bunches of quartz, has been worked by adits and open cuttings at several places on the eastern hill-slope: but here also work had to be given up for the same reason as in the former case. Some of the quartz-bunches paid very well, but ran quickly out, and it took all the profit made, and more, to prospect for others. In the neighbourhood of this place there are the ruins of a small battery of 5 heads of revolving stamps.

The Shamrock Reef.—This lies half a mile north-eastward from the last mentioned workings, up the range, and consists of a bunch of rather good-looking quartz, 2-3 feet thick at the surface, but running out at 4 feet in depth; as proved by a small shaft sunk on it. In strike it is traceable either side of the shaft for some distance, though apparently growing thinner. A trial crushing of two tons of the quartz is said to have paid 1 oz. 18 dwts. of gold. As this return must no doubt have left a good profit over working expenses, it seems strange that the reef has not been opened farther.

Main Reef of the Shag Valley Lease and Freehold Company.—This is the most important reef opened in the district. It lies not far from the Shamrock Reef, and has been worked by large open cuttings, extending, with few interruptions, for 6-7 chains in length, along the slope of a steep range. It lies between the beds of the country, striking N. 40° W., and dipping north-eastward into the range, at angles varying from 25-35°. Its thickness ranges from 2 feet to (in places) over 4 feet, and it has the footwall pretty well defined throughout, but its hanging wall is broken and full of small leaders. It consists mainly of quartz, which in large, solid bunches and veins lies mostly along the footwall, whilst towards the hanging wall there is a deal of mullock intermixed. The quartz is good-looking, seamy, and slightly impregnated with pyrites. Regarding the yields from this reef, and the operations of the Company, Mr. Harvey gave me the following particulars :—After auriferous stone was discovered in the reef, and satisfactory prospects obtained by tin-dish trials from several places along the outcrop, as far as the workings at present extend, 4 tons of the stone were sent to Ballarat, Victoria, and crushed at a good machine, with a result of 16½ dwts. of gold per ton. Another trial crushing of 1½ tons, executed at the Government battery, Dunedin, gave 1 oz. 6 dwts. of gold. Encouraged by these satisfactory results, the Company erected crushing machinery, and gave the supply of 1,000 tons of stone from the reef in contract; but the first 500 tons paid at the rate of 4 dwts., the second at the rate of only 3 dwts. of gold per ton. These low returns did not, of course, by far cover the expenses, and the working of the mine was stopped in consequence.

The crushing machine of the Company stands in the gully, near the first-mentioned workings, about half a mile away from those last noted, and is very well constructed. It consists of two batteries, each of five heads of revolving stamps, supplied with self-feeding hoppers, and driven by a steam-engine, the necessary supply of water being obtained from a good-sized reservoir, constructed a little higher up the gully. In front of the batteries lie common amalgamated copperplate tables, and below these follow blanket-strakes 14 feet in length, and with a fall of ¾ inch per foot. A revolving barrel is provided for the treatment of the blanket-sand.

Whilst considering the Company to have acted very unwisely in erecting expensive machinery before the reef had properly been opened and prospected, to say 50-80 feet in depth, I am of opinion that it certainly deserves this trial, now that the machinery for testing the quartz is available. For, as regards the great discrepancy between the gold returns of the last, and those of the trial-crushings, it seems likely in a great measure to have arisen through the contract for the provision of the 1,000 tons of quartz to the mill, inasmuch as the old workings plainly show, that far more mullock (from the hanging wall) was taken than quartz. And from what Mr.

GERMAN "TREPPENROST" OR STEPFURNACE.

for the burning of Brown Coal for Boilers.

Fig. 1.

Longitudinal Section according to a b.

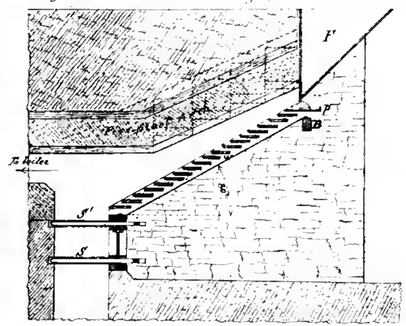
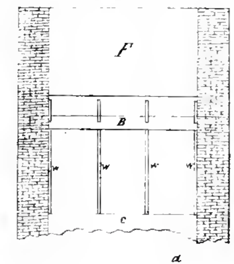


Fig. 2

Part Plan shewing cheeks W.



Cheeks W with steps

Fig. 3

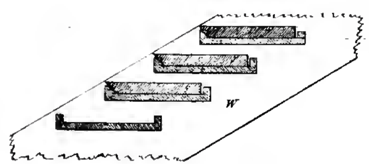
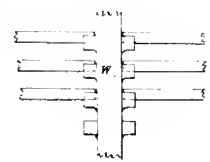


Fig. 4



Harvey told me, it seems also doubtful, whether these quarry-like openings are actually at those places which furnished the stone for the trial-crushings.

APPENDIX 13.

THE GERMAN "TREPPEN-ROST" OR STEP-FURNACE FOR THE BURNING OF BROWN COAL.*

Construction (*See Fig.* 1-4, *No. IX.*)—Above an opening of 45 centimeters in width, communicating with the ashpit, lies a slide-frame *S*, with massive slides of 10-12 millimeters in thickness, the whole resting in front, for the sake of solidity, upon a cast-iron plate *a*, 13 centim. broad, and 4-5 centim. thick. Upon the slide-frame *S* is placed a cast-iron double T support, 24 centim. in height, 13 centim. broad, and 12 millim. thick, and upon this lies a second slide-frame *S*. The slides of this frame being 25 millim. thick, are, however, perforated or broken longitudinally, in order to form a grating; or better, movable fire-bars 5-7 centim. thick, are used instead of the broken slides, which are liable to crack. Upon the slide-frame *S* lies a second cast-iron plate *c*, of the same dimensions as *a*, and at suitable height a third cast-iron bar *B*, 9 centim. high and 6 centim. broad, is fixed into the side walls of the furnace. The length it is let into the walls is about 15 centim., whilst *a* and *c*, and the slide-frames *S* and *S* enter the walls only about 8 centim. with their ends. Upon the, what may be called, cross-supports *B* and *c*, rest now, with their ends the cast-iron cheeks *W* in such a manner that they may be freely shifted broadways, and carry step-like (hence the name of the furnace) the several fire-bars of which the upper one *p* is about three times broader than the rest. Above *p* is fixed the cast-iron supply-funnell *F* serving for the receipt of the fuel, and which is sometimes furnished with a slide for regulating the supply of fuel into the furnace. The fireplace is fixed between two stone-walls, and covered by a fire-proof arch, which is either inclined and smooth, or, as indicated by the dotted lines, broken step-like for the purpose of offering to the combustible gases more heated surface on which they strike, and are set burning. The cheeks *W* are 25 millim. thick, and 10-12 centim. broad, and placed at 0·4 to 0·6 meter distance from each other. The whole length of the furnace is generally 2 meters or smaller, the breadth equal to, or less than 1·3 meter; and the inclination of the cheeks *W* is most advantageously at an angle of 30° (*i.e.*, for the burning of brown coal, for which these furnaces are most suitable, and nearly exclusively used).

The most approved connection of the fire-bars, with the cheeks *W* is shown in figures 3 and 4. Their thickness is 1-12 millim.,

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* See "H. von Reiche Anlage und Betrieb der Dampfkessel." Leipzig, 1872.

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the vertical distance between two bars 19-20 millim., the distance between their surfaces 27-32 millim., their breadth 118-120 millim., and they project one over the other about 47 millim. The working of such a furnace requires much less strength and intelligence than that of the common plane fireplace. The funnel *F* is filled with the fuel, and, according as the latter burns off the steps (which is easily seen), the fireman pushes a fresh lot from top downwards by means of a spade-like tool, introduced between the lower edge of the funnel *F* and the top bar *p*. The gradually accumulating ashes are from time to time removed from the fire-bars by means of a flat piece of iron, which is moved hither and thither over the latter. In order to remove cinders and ashes from the upper slide *S'*—(*S* being always kept a little open to let draught in for perfect combustion)—the slide *S* is first shut, then *S'* opened to let the ashes and cinders drop upon *S*; then *S'* is shut again, and fuel stoked down to cover it, and now, finally, *S* is opened so that the ashes, etc , can fall down into the ash-pit. In this manner the detrimental introduction of a large amount of cold air into the furnace is entirely avoided. The chief advantage of this furnace consists in the steady, nearly continuous, burning of the fuel, and that with proper regulation of the draught the combustion can be rendered close upon perfect, whilst all the smoke is consumed. To this has to be added another great advantage, namely, that during the supply of fuel no unnecessary amount of cold air is introduced into the furna ce, and that, as previously mentioned, a common workman is able to serve the latter easily and well, and without being exposed to any strong heat bursting into his face. The furnace has also, however, some drawbacks, viz., that no coal can be burned in it that bakes or clogs, and that the fuel rests upon a larger area of iron, being, therefore, much more cooled, and for a larger surface extent prevented from burning, than in the common plane furnace.

GENERAL INDEX.

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ERRATA.

Page 15. The foot notes ‡ and § should be transferred.
„ 28. The foot note * refers to the age of the Manipori formation.
„ 40. Line two from top, for Mr. Potts read Mount Potts
„ 39. Foot note for page 265, read page 263.
„ 46. Foot note ‡, for page 184 read page 106.
„ 67. Line six from bottom for "scattered" read "scratched."
„ 80. Fig. 21, for "from the north" read "looking north."
„ 135. Between numbers four and five insert *Gasteropoda*.

In the Map, that portion of the Maitai formation east of the Clutha, opposite to Balclutha, has been inadvertently colored as if it were basalt.